RISK AND ITS ANALYSIS IN THE SUSTAINABILITY ASSESSMENT OF THE BUILT ENVIRONMENT

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How to build sustainably is arguably the pre-eminent question of our time. The construction industry and the built environment which it creates have a substantial impact on a range of sustainability issues. Sustainability assessment exists to measure the impacts of sustainability. However, the existing range of assessment methods frequently fails to take risk in the process or the outcome into account. The purpose of the research presented in this paper is to present a generic approach to estimating risks in sustainability assessment for the built environment. This approach defines generic cases of the probability and consequence for risks in sustainability assessment. An outcome matrix has been created to define the severity of each risk based on the associated probability and consequence. Appropriate responses are proposed to then manage the risks. Using the context of sustainability assessment for housing, the specific risks associated with the Ecohomes assessment method are explored. This research demonstrates through applying risk analysis that there are unacceptably severe risks associated with the weighting mechanism, regional differences, fixed parameters and thresholds, the range of coverage of the indicators and the heavy data requirement. However, the analysis demonstrates that there are a number of in-built mechanisms which make Ecohomes resistant to specific risks, and there are also some risks which may not be severe for specific problem situations. The application of risk estimation allows novel insights into the sustainability assessment process and is transferable to other sustainability assessment methods for the built environment.

Keywords: BREEAM, Ecohomes, risk analysis, sustainability assessment.

INTRODUCTION

Sustainability and sustainable development are arguably the pre-eminent issues of our time. Many of the origins of current research and development in this area can be traced back to the Brundtland Commission's Report, "Our Common Future" (WCED 1987). In the intervening years there has been debate as to exactly what sustainable development entails and how it can be achieved. There are many perspectives, but it is generally agreed that the aim is to achieve the goal of meeting current needs whilst preserving the ability of future generations to do likewise. In doing so it is generally appreciated that there are three dimensions. These three dimensions are social, economic and environmental (Parkin *et al.* 2003). Ultimately the goal must be to head towards being sustainable. Sustainability assessment is a vital tool in considering whether development is sustainable: that is whether changes are decreasing or

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increasing our ability to be sustainable (Pope *et al.* 2004). Effective, robust assessment of sustainability is therefore vital to take account of the complexities and interactions of the social, economic and environmental dimensions (UN 2007). This is particularly so in the assessment of the built environment. BREEAM (Building Research Establishment's Environmental Assessment Method) is commonly referred to as the first simplified environmental assessment methods for buildings (Birtles 1997; Cole 1998). It is simplified because it allows projects to be readily assessed on a common framework without necessarily carrying out a detailed impact assessment for each one. BREEAM is a UK-based assessment and has been adapted for application to Canada, Hong Kong and Australia (UKGBC 2007). BREEAM is one of the most commonly used sustainability assessment methods for the built environment in the UK.

What are the risks in sustainability assessment?

The purpose of this research is to investigate how risks can be assessed in sustainability assessment and to develop a generic approach for doing so. This will use subjective probability and consequence and highlight where sustainability assessments are robust and where further investigation of the risks is requires. If sustainability assessment is wrong or incomplete then the outcome will not be head towards the goal of sustainability. One of the problems in the standard approaches to sustainability assessment is that there is no published account of the uncertainties which exist. These uncertainties exist in two key areas: firstly the development of the methods and secondly the application of the techniques. Frequently the methods are provided as a 'black-box' type system which produces a deterministic outcome. It is therefore hard to make a judgement on how risk-prone a sustainability assessment method is.

The underlying risk in sustainability assessment is that the wrong outcome results from the assessment. There are obviously degrees to which it can be wrong. For example it could be fundamentally flawed, or it could be wrong in only one area. Applying the framework of risk management to analyse and respond appropriately to these risks allows the potential problems in sustainability assessment to be seen.

The objective of applying a risk management framework to sustainability assessment methods is to establish where the uncertainties exist in the process and where the risks which may result in a wrong assessment of sustainability lie (Blockley and Heslop 2001). Many of these risks will be hazards where the assessment can fail in its measurement. Sustainability assessment, and in particular sustainability assessment of the built environment, has failed to take due account of the risks associated with the estimate of sustainability (Roscelli and Bellomo 1997).The application of a risk management framework to sustainability assessment will allow these uncertainties and hazards to be understood in more depth. This will allow a further evaluation of high severity risks where they exist in the process. Sustainability assessment methods can then be modified to control and reduce the risks. This approach is designed to deal with the risks at the development stage of sustainability assessment tools. The analysis of risks in this way will guide and direct the development of the assessment and will produce guidance on how the tools should be applied.

RISK ASSESSMENT IN SUSTAINABILTY ASSESSMENT

Previous research has identified a comprehensive set of risks associated with sustainability assessment of housing (Forbes *et al.* 2008). This was done through a workshop and subsequent validation and supplementation via a questionnaire. These risks will be assessed in this research. Subjective probability and consequence is the

most commonly used method for risk assessment (Akintoye and MacLeod 1997). The approach is based on the assessment of the probability of the event occurring in conjunction with the consequences to the objective of the given event occurring.

Setting the probability and consequence levels

A five-point scale has been developed for the probability and consequences with risks in sustainability assessment. The probability scale, Table 1, ranges from 'Almost Certain' to 'Rare'. The intermediate values can be applied as appropriate. There are indicative probabilities assigned to each level. The most likely (almost certain) considers probabilities in excess of 85% and the least likely (rare) less than 1%. The probabilities were adapted from the Risk Analysis and Management for Projects guide (ICE *et al.* 1998) which also included a sixth level of probability less than 0.01%. However, such a small probability in comparison to the next level of less than 1% was felt to be unnecessary for assessing the risks in sustainability assessment methods.

In a similar manner, the consequences are defined for the purposes of this research in a five-point scale as given in Table 2. These five points relate to the effect of the risk on the assessment outcome. A brief description of the effect on the assessment of sustainability is provided. For instance, the highest level is catastrophic, for example for an assessment that concludes a development is sustainable when in actual fact it is not.

Table 1 Probability descriptors for probability and consequence approach

Description	Scenario/Details	Indicative Probability
Almost Certain	Is present, or is most likely present in the assessment	85-100%
Likely	Is most likely/more than evens chance the risk is in the assessment	50-85%
Possible	Might be in the assessment	15-49%
Unlikely	Could potentially be in the assessment	1-15%
Rare	Risk will only be in the assessment in extreme circumstances	<1%

Table 2 Consequence descriptors for probability and consequence approach

Description	Scenario/Details
Catastrophic	Will lead to a fundamentally wrong assessment of sustainability
Major	Will lead to a wrong assessment output
Moderate	Will increase the complexity of the output/Moderate errors in the output
Minor	Will have a minor effect on the output of the assessment
Insignificant	Will not affect the output score significantly

Setting the severity of the risk

The probability and consequence are combined into levels indicating the severity of the risk. These severity levels define the actions which must be taken for each of the risks. Four levels have been developed. Each is assigned a required action as detailed in the table. The severity levels and responses are: Intolerable (Steps must be taken to reduce or eliminate this risk); Undesirable (Further investigation is required to investigation this risk and define further. If risk is to be retained, guidance is to be

provided to mitigate the effects or probability of this occurring.); Acceptable (Retain and acknowledge risk), Negligible (Can be ignored).

There is a range of approaches to assign probability and consequences to a problem and consider the appropriate severity (AS/NZS 2004; Godfrey 1996; ICE *et al.* 1998). The severity of a risk is defined by combining the probability and the consequence for each one. This can be done in two ways. Firstly, an absolute value (for instance numbers 1-5) is assigned to the probability and consequence. The risk severity is then determined by comparing the product of these two numbers to a pre-defined threshold. Secondly the matrix combining probability and consequence is defined by applying a reasoned approach to define the severity of each combination (Godfrey 1996). Where this second approach is suggested it is stated that the combined levels should be tailored to meet the individual problem (AS/NZS 2004).

Probability and consequence are combined to define the appropriate response. A tailored matrix for use in sustainability assessment is proposed in Figure 1. A product approach would tend to consider insignificant and almost certain risks at the same level as catastrophic and rare risks. For the purposes of sustainability assessment this was not considered appropriate, as an issue which would result in fundamentally wrong assessment of sustainability should at least be considered in more detail, regardless of how likely it is to occur. Therefore a subjective, reasoned, approach was used to assign the severity to the combined levels of probability and consequence. This assigned intolerable and undesirable categories to all catastrophic risks to ensure further investigation of these. Similarly major risks, which will lead to a wrong assessment, must all be investigated further except for those which only occur rarely. The moderate and minor risks have a spectrum of severities covering all four levels. Finally, risks of insignificant consequence do not need to be considered in any further detail, except for an acknowledgement of those that are likely or almost certain to occur as outlined in Figure 1. In effect, this process has placed a higher weighting on the consequence of the risks than on their probability.

Figure 1 Outcome combinations for probability and consequence approach

		Consequence				
		Catastrophic	**Major**	**Moderate**	**Minor**	**Insignificant**
Probability	**Almost Certain**	Intolerable	Intolerable	Intolerable	Undesirable	Acceptable
	Likely	Intolerable	Intolerable	Undesirable	Undesirable	Acceptable
	Possible	Intolerable	Undesirable	Undesirable	Acceptable	Negligible
	Unlikely	Undesirable	Undesirable	Acceptable	Acceptable	Negligible
	Rare	Undesirable	Acceptable	Acceptable	Negligible	Negligible

ASSESSING RISKS IN THE ECOHOMES ASSESSMENT

A key part of the built environment is the housing sector. The potential for achieving a sustainable built environment through housing has been demonstrated by many authors (eg. Lovell, 2004); it has therefore become a focus for government targets on, primarily, reducing carbon emissions (Stevenson and Williams 2007). Therefore, the risks associated with the domestic BREEAM version, Ecohomes, will be investigated in this research.

How Ecohomes works

Ecohomes is the domestic version of the BREEAM family. It was developed in 2000 and has undergone revisions in 2003, 2005 and 2006 (BRE 2006). The most recent, 2006, version assesses environmental performance against eight headline categories. The categories are Energy, Transport, Pollution, Materials, Water, Land use and ecology, Health and wellbeing, Management. The scores for each category are combined into a total percentage score for the whole development. This score is then translated to a rating scale of 'Pass', 'Good', 'Very Good' and 'Excellent'.

Assessing the risks in Ecohomes

The generic approach for assessing risks in sustainability assessment was used to determine the risks in the Ecohomes assessment method. This process used the full set of 48 risks which had been developed in previous research as being associated with sustainability assessment of housing (Forbes *et al.* 2008). This process allows a high level overview of the risks in sustainability assessment to be seen and for the characteristics of the assessment method which open it up to risks to be identified. The levels of probability and consequence were assigned to each of the 48 risks based on the definitions in the previous section. These were assigned by using an in-depth knowledge of the assessment methods based on the author's personal experience as a qualified and registered Ecohomes assessor, and published literature and articles relating to the assessment method. Additional, further background understanding was obtained from the risk management workshop where the risks were initially identified.

Figure 2a-c contains a full set of the risks and the corresponding probability and consequence of each in the Ecohomes assessment method. Additional background notes supporting the defined levels are included along with the overall severity of the risks.

What are the risks in Ecohomes?

The risk analysis undertaken demonstrates the severity of the risks associated with the Ecohomes assessment method. It allows a high level assessment to be made of the risks in sustainability assessment and in particular the Ecohomes assessment method. The risks which emerged from the analysis of Ecohomes are discussed below.

Low Level Risks

An analysis of the overall level of risk in Ecohomes showed that there were two risks which were negligible. There were 19 at an acceptable level, and 15 and 12 at undesirable and intolerable levels respectively. The negligible risks are important because it is these areas which demonstrate where Ecohomes is extremely robust. Two strengths of Ecohomes result in these outcomes. Firstly, the context of an Ecohomes assessment is clearly defined within the boundaries of housing. This is facilitated further by the remainder of the BREEAM family which is designed to take account of other types of building.

The second aspect of Ecohomes which inherently minimises some the risk is the prescriptive nature of the assessment. This allows all assessments to be carried out using a common reference point and protects against subjectivity by the assessor.

In addition to the negligible risks Ecohomes had 18 risks which were acceptable. These risks are considered to be of a sufficiently low combination of probability or consequence that they can be retained. This is the largest group of risks within Ecohomes, and again demonstrates that there are effective built-in mechanisms to

keep the severity of the risks low. The characteristics which keep it low are the established nature of Ecohomes in UK as an assessment method, and its context within the BREEAM family. Similarly, the expertise and experience within BRE in developing the suite of tools and the consultation undertaken to develop them contributes to keeping the severity of these risks acceptable. The process of Ecohomes is rigid in collecting evidence, awarding credits and quality assurance checks. There is very little scope to allow deviation from a prescribed path. This is of benefit to risks in measuring, accuracy, complexity and conceptual issues.

High level risks

Despite the ability of Ecohomes to maintain the severity of the risks at an acceptable level or less for 20 out of 48 risks, there remain 28 risks which are undesirable or intolerable. These risks require immediate attention or further investigation. Firstly, Ecohomes was originally an environmental assessment method; an increasing number of social issues have been incorporated in recent revisions. A pure environmental assessment may be appropriate for some applications. However, the extent of its coverage in three dimensions should be established. The risk assessment has critically highlighted the lack of the economic dimension in the assessment. There are also weightings are applied to each of the eight categories. The effect and consequences of these should be investigated. This is coupled with trade-offs in the assessment making Ecohomes a weak sustainability measure

Additionally, Ecohomes is a design-stage assessment and there is no check on the post-construction outcome of the dwellings. There is little account is taken of differences between rural and urban settings and new-build against existing stock. The assessment methodology is restricted solely to housing. Alternative tools should be used if a wider assessment context is required. These are partly controlled by rigid guidelines set by BRE to maintain rigour in the process (eg. licensed assessors, quality assurance, updates). However, these must be observed to ensure the risks are minimised.

There is a heavy data requirement to carry out an assessment. The full extent of the data requirements should be investigated. This heavy data requirement impacts on the verbose nature of the report. Despite this heavy data requirement the output is a fixed percentage value. The appropriateness of such a point value should be investigated. Included in calculating this fixed value are a range of fixed parameters and thresholds pre-defined by BRE. The effect of these fixed parameters and thresholds should be considered in more detail. Ecohomes also relies on other tools to define the output (eg. SAP2005, Considerate Constructors Scheme). These are all widely acknowledged industry tools, however their appropriateness should be considered by the assessor organisation prior to use. These risks have been shown, in a subjective approach to be of an unacceptably high level. Therefore they need further investigation, or have control measures put in place to reduce the risks to an acceptable level.

CONCLUSIONS

There are risks in sustainability assessment methods for the built environment which are not properly investigated. The research presented in this paper has investigated the process of managing risk in sustainably assessment and proposed a generic means of their analysis. The probability and consequence approach presented in through this research is an initial step in the risk management process to manage these risks which

1	Accuracy	Inconsistent Information	Is there inconsistent information in the assessment?	Unlikely	Moderate	The established nature of Ecohomes has put it under scrutiny and led to several revisions. As far as can be established there is not inconsistent information.	Acceptable
2		Errors in tools/data used for models	Are there errors in the tools and the data that is used to carry out the assessment, and/or in any associated tools required to carry out the assessment?	Possible	Major	The data used to build the model relies on a number of fixed parameters, and thresholds, and other measures which are used (*eg.* Considerate Constructors Scheme, SAP Assessment *etc.*). It is possible that errors exist in these; however all are well established techniques which are used throughout the construction industry.	Undesirable
3		Reliability of Data	Is the data in the model unreliable?	Likely	Catastrophic	The model includes several fixed parameters and thresholds of which the reliability is unknown and could affect the output of the assessment.	Intolerable
4		Transparency/Boundaries	Are the boundaries for the assessment not clearly defined and stated in the assessment process?	Rare	Catastrophic	Ecohomes is a prescriptive method which can only be applied to housing developments. Account is taken of dwellings within the development and no account is made of infrastructure or provision of amenities by the developer.	Undesirable
5	Appropriateness	Acceptability	Is the assessment method accepted by those who are using it and those who are to receive and act upon/use the output?	Possible	Minor	Ecohomes is widely used by the main providers of social housing. It is accepted and funding can be dependent on it. This risk does not directly affect the development of an indicator but does ensure that an indicator is appropriately used and acted upon.	Acceptable
6		Parties involved	Is the assessment inappropriate for all parties involved and are these well defined?	Rare	Major	The assessment clearly defines the parties involved and highlights the responsibilities of each.	Acceptable
7		Misuse of Indicators	Could the indicators be misused, rendering the assessment in-appropriate?	Rare	Catastrophic	There are considerable consequences which could occur if the indicators are mis-used. However, Ecohomes required licensed, trained assessors to carry out the assessment and a rigorous quality assurance (QA) and audit process making this risk rare.	Undesirable
8		Priorities	Are there mis-placed priorities in the assessment which make it in-appropriate?	Likely	Catastrophic	Ecohomes originated as an environmental assessment method. There is still therefore a focus on environmental issues although in recent revisions of the model it has included some social issues.	Intolerable
9		Scale	Is the scale of the assessment in-appropriate and un-realistic?	Possible	Moderate	Ecohomes is used extensively and covers the scale of housing developments. The other BREEAM assessment methods take account of other buildings. There are concerns that the scale of the assessment is unrealistic as it takes account of many factors which are beyond the control of the developer (*eg.* amenities).	Undesirable
10		Time Dependency	Does the assessment fail to take due account of changing times and understanding?	Unlikely	Major	The guidance documentation is updated on a regular basis and the baseline for assessments is the current building regulations in different parts of the UK. This accounts for changing times and understanding, provided the current version of the guidance documentation is used.	Undesirable
11	Communication	Marketing	Is there a lack of clear marketing to communicate the process and output?	Unlikely	Moderate	Ecohomes has a considerable marketing presence in outlining the process and its application. However it is not considered that this is covering any hidden agenda as the guidance is freely available and assessors are trained.	Acceptable
12		Outputs/Inputs	Are the inputs and outputs to the assessment not clearly communicated to the required parties?	Possible	Moderate	The inputs and the outputs from the assessment are clearly outlined in the assessment report and certificate. However, this has a tendency to be verbose. It is possible that the output may be mis-interpreted, but this is not an issue with the assessment process.	Undesirable
13		Presentation	Are the inputs and outputs not clearly presented?	Possible	Moderate	The inputs and the outputs from the assessment are clearly outlined in the assessment report and certificate. However, this has a tendency to be verbose. It is possible that the output may be mis-interpreted, but this is not an issue with the assessment process.	Undesirable
14	Conceptual Issues	Beliefs/Understanding	Is there opportunity for the beliefs of the parties involved to affect the output of the assessment?	Rare	Major	The prescriptive nature of Ecohomes, the training of assessors and QA checks mean that there is little scope for beliefs to influence the output.	Acceptable
15		Practicalities	Is the assessment impractical so that it will not be embraced by all parties involved?	Likely	Major	There is concern relating to the amount of information and evidence which must be collected to carry out an assessment. Potentially, the assessment may not be embraced by all because of this.	Intolerable
16	Ignorance	Experience/Understanding	Is there ignorance in experience and understanding of those who have developed/applied the assessment?	Rare	Major	The Ecohomes QA and training process makes the possibility of a lack of knowledge in carrying out the assessments a small risk. The knowledge of BRE in developing sustainability assessments is not considered to be a problem.	Acceptable
17		Knowledge	Is there ignorance in the knowledge of those who have developed the assessment?	Rare	Catastrophic	BREEAM Offices has been in existence since 1990, and Ecohomes since 2000. Over this time BRE have developed extensive knowledge in sustainability, and so ignorance in this area is unlikely.	Undesirable

Figure 2a Risks assessed in Ecohomes

Figure 2b Risks assessed in Ecohomes

19	Lack of consensus	Appropriate Indicators/Impacts	Is there a lack of consensus amongst the parties involved regarding the appropriate indicators/impacts to include in the assessment? Does it take account of the three dimensions of sustainability?	Likely	Major	Ecohomes prescribes the indicators which must be measured for each category. Ecohomes takes no account of economic issues. There are weighting issues associated with each of the different categories and indicators which should be considered in more detail.	Intolerable
20		Context Specificity	Is there a lack of consensus between parties involved in the specific context for the assessment?	Rare	Minor	This is a rare risk as the context is defined as a housing development for Ecohomes. The consequence is moderate because if the context is not understood it could affect or complicate the assessment.	Negligible
21		Definition	Is there a lack of consensus amongst the parties involved regarding the definition of the assessment?	Possible	Moderate	It is possible the different parties may not fully understand the extent of the project definition. The project is clearly defined in the guidance, but it should be noted that there are issues with differences between new-build and refurbishment; additionally the rural/urban distinction may potentially cause issues.	Undesirable
22	Legislative Framework/Policy	Agency requirements	Are there governmental/NGO agency requirements which could affect the output of the assessment?	Rare	Major	It is unlikely that external requirements (potentially funding requirements) would affect the output of the assessment, as the prescriptive nature of Ecohomes prevents this. However if this was possible, it would have a major impact on the output.	Acceptable
23		Building Regulations	Could the building regulations adversely affect the outcome of the assessment score?	Rare	Major	The base line for Ecohomes is the building regulations. The building regulations will affect the output by prohibiting projects which fall short. This is not seen as a problem likely to adversely affect the score	Acceptable
24		Funding Issues	Are there funding issues from government/private funding which could affect the output of the assessment, or could affect it in carrying out the assessment?	Unlikely	Major	In public sector housing, funding is frequently tied to achieving a particular Ecohomes score. However, because Ecohomes is so prescriptive the scope for deviation is relatively small.	Undesirable
25		Government legislation	Is there current or potential government legislation which could affect the output of the assessment?	Likely	Major	It is possible in Ecohomes that a project may be registered under a version with lower standards to avoid the impacts of future legislation.	Intolerable
26		International Alignment	Is the assessment mis-aligned with international standards and assessments?	Unlikely	Minor	BREEAM is seen, globally, as a leader in the sustainability assessment of buildings. Due to this it leads the way in setting international standards for sustainability assessments, and has been adapted for use outside the UK (*eg.* Hong Kong).	Acceptable
27		Planning	Are there planning constraints which could have an impact on the assessment output?	Unlikely	Minor	The prescriptive nature of Ecohomes means that planning constraints should not have an effect on the outcome of the assessment.	Acceptable
28	Method of Measurement	Bias	Is there bias in the assessment process to particular elements, or to one party involved in the assessment?	Likely	Major	For historical reasons within BREEAM there is a bias in the process for environmental elements, although not necessarily to one party or another.	Intolerable
29		Interpretation	Is the assessment open to mis-interpretation/lack of definition in the measurement?	Rare	Major	The measurement of the input values is clearly defined in the guidance documentation.	Acceptable
30		Scientific Knowledge	Is there un-realistic scientific knowledge required in measuring the inputs or outputs for the assessment method?	Unlikely	Moderate	A reasonable level of knowledge and competency is required to carry out the assessment. However this is not generally beyond those with knowledge of housing and construction, and the training and competency of the assessors ensures that the probability of this occurring is low.	Acceptable
31		Trade offs	Is the assessment open to trade-offs between issues?	Almost Certain	Moderate	The 'trade-off' issue in sustainability assessment is one of great debate. However, a moderate consequence has been allowed for in this assessment because the mechanism does not allow maximum points to be scored unless a maximum is achieved in all of the indicators.	Intolerable
32		Weightings	Are there weightings in the assessment which could adversely affect the output of the assessment?	Likely	Major	There are weightings in Ecohomes which have been defined by industry consultation. However, there is no allowance for regional variations, and the weights will have an effect on the overall score.	Undesirable

Figure 2c Risks assessed in Ecohomes

33	Omission	Life Cycle	Does the assessment process fail to take account of the full life-cycle of the project?	Possible	Major	The assessment takes account of the life-cycle regulated energy requirements, but no account is made for whole life costs, or non-regulated energy requirements for appliances other than white goods. There is therefore a possibility that this risk is present.	Undesirable
34		Measurement	Are there indicators omitted/unnecessarily included in the assessment which could affect the measure of sustainability?	Almost Certain	Major	It is noted that Ecohomes does not take account of economic issues. The ability of Ecohomes to assess fully the environmental and social elements is not clear.	Intolerable
35		Stakeholder Views	Are there views of specific stakeholders omitted from the assessment?	Unlikely	Moderate	In the development of the BREEAM family over time, BRE have consulted widely on the process and methodology. It is available in the public domain, and assessors and individuals have the opportunity to raise issues with the BREEAM office.	Acceptable
36		Tacit knowledge	Is knowledge of the assessment held within individual parties involved in the assessment and thus adversely affecting the output of the assessment?	Rare	Moderate	Knowledge of the assessment is held in the overall report which is produced by the assessor. The client, or owner of the project, will receive a copy of the certificate and potentially a copy of the report outlining the overall rating. However, none of this will affect the outcome of the assessment.	Acceptable
37		Unknowns	Is there the possibility of omissions which could adversely affect the output of the assessment?	Likely	Major	Ecohomes requires an extensive body of evidence to perform the assessment. It is likely that unless all the evidence can be collected for a particular issue the credits will be withheld. Therefore it is likely that the score will be reduced on the lack of proof. This withholding of credits will result in scores that are not artificially high. However, omissions are of greater concern and could have a larger impact on the score compared to withholding points in the assessment.	Intolerable
38	Over complexity	Calculation	Are the calculations required for the project over-complex?	Possible	Moderate	All of the calculations which are required for the assessment are subject to spot checks by the assessor and by the QA procedures. The SAP assessment is not, but must be carried out using certified software. All of this mitigates the risks associated with carrying out the assessment. However, a risk which remains and needs further investigation is the number of calculations which must be considered.	Undesirable
39		Data is complex	Is the data required for the assessment so complex that it might affect the output?	Possible	Minor	The data which is required for the assessment is not generally considered to be beyond the data normally required or available in a housing development.	Acceptable
40		Over Simplified	Is the data required for the assessment so over simplified that it might affect the output?	Rare	Moderate	It is not considered that the data required to carry out an Ecohomes is so over-simplified that it would affect the score.	Acceptable
41		Timing	Does the timing of the project increase the complexity which could affect the output of the assessment?	Possible	Catastrophic	The timing of the assessment is not fixed, which can cause issues for the assessment process. The largest risk is in relation to the processes itself that is carried out at the design stage and does not take full account of the construction process, or post-construction/occupancy review.	Intolerable
42		Too difficult to understand	Are the assessment and/or its inputs/outputs too difficult to understand?	Possible	Minor	The assessment report and certificate are written in a simple manner, highlighting what has been done to achieve the rating. Additionally the inputs which are used are explained in detail.	Acceptable
43		Too Expensive	Is it too expensive to carry out an assessment?	Likely	Moderate	The expense of carrying out an assessment does have the potential to prohibit the assessment in the first place. Secondly the expense of gathering the evidence may prevent a comprehensive assessment.	Undesirable
44		Too Many	Are there too many inputs to measure to carry out an assessment?	Likely	Major	There are a large number of inputs that need to be collected to carry out an assessment However, the large number and the interrelationships could have an adverse effect on the output of the assessment.	Undesirable
45		Too Subjective	Is the assessment too subjective and open to mis-application?	Rare	Minor	The assessment process is prescriptive and therefore not open to subjectivity. This is therefore eliminated from Ecohomes.	Negligible
46	Value for Money	Cost & Boundaries	Is the cost of the assessment ill-defined, and not connected to the boundaries which are defined for the assessment?	Possible	Minor	The assessment has clear boundaries, and the QA fees are clearly defined. However, the cost to carry out an assessment is dependent upon the evidence which is required for the appropriate credits. Thus, the least expensive to obtain credits will be sought first, which could skew the score.	Acceptable
47		Cost-benefit	Is there no cost benefit for those involved in the assessment for actually carrying out the assessment?	Possible	Minor	This risk must be assessed on a case-by-case basis as there is no requirement with Ecohomes to carry out such an assessment. However, it may not be a problem in every situation.	Acceptable
48		Life cycle costing	Is there no value for money obtained over a life cycle in the use of the assessment?	Likely	Moderate	The assessment takes no account of financial benefits, either initially, or over the lifecycle, therefore the whole life values of the assessment cannot be estimated using Ecohomes.	Undesirable

has not been applied before. This approach is generic and could be applied to a set of identified risks in any sustainability assessment method. There are, however, limitations associated with applying probability and consequence to the problem, not least the subjective nature of the approach. Its application to the Ecohomes assessment methods has been successfully demonstrated in this research. Further research should apply the approach to other assessment methods (eg. CEEQUAL, Code for Sustainable Homes) to determine its effectiveness and generic capabilities.

Beyond showing the applicability of the probability and consequence approach the particular risks associated with Ecohomes have been assessed. This has shown that there are several built-in strengths which make it robust. These are controlled by rigorous updates, quality assurance, evidence collection and assessor training. However, there are a number of risks which require further investigation to ensure appropriate controls can be put in place. There are four ways of dealing with these: firstly the risks which are inherent which should be considered on a case-by-case basis, secondly the risks which require existing safe-guards to be put in place before they are controlled (eg. the standard reporting format), thirdly those risks which are affected by the Ecohomes process and finally those risks which require further investigation. These four groups should be considered in more detail to gain a greater understanding of the risks in Ecohomes.

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