Implementing Sustainability Knowledge into the Built Environment: An Assessment of Current Approaches

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Abstract
The Architecture/Engineering/Construction (A/E/C) Industry is beginning to adopt new methods and adapt current practices to better incorporate the concept of sustainability into the built environment. One approach for implementing the concept of sustainability takes the form of written checklists, handbooks and guidelines targeted for practitioner use. These documents represent a significant and growing body of knowledge about sustainability with respect to the built environment. Presented within this paper is an assessment of the sustainability related knowledge contained in 26 such documents. The assessment involved creation of a database of statements extracted from each of the selected documents. Each statement was classified by three factors: 1) level of domain specificity, 2) scale of impact, and 3) facility life cycle phase. A statistical analysis was utilized to analyze the relationship of current sustainability knowledge with respect to each classification factor. Results of the analysis identified current areas of emphasis and nonemphasis of the application of sustainability knowledge to the built environment.

Keywords
Sustainability, Database Creation, Statistical Analysis

Introduction
Sustainability is an issue gaining importance with all built environment stakeholders. Users, owners, designers, constructors, and maintainers from all sectors are actively seeking techniques to create a built environment which will (adapted from [1]):

A) Efficiently use all resources (energy, water, material, land) and minimize waste
B) Conserve the natural environment (the source of all resources), and
C) Create a healthy built environment for existing and future generations.

These three objectives extend from recognition of the potentially profound long term impacts of human population and technology on natural ecosystems. As an industry we are beginning to ask: how does the built environment play a role in the larger context of the global sustainability of the earth and the humans which reside there? How can we create "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [2]. Given this sustainability emphasis, we can no longer use only the traditional issues of time, cost, and quality to measure performance of building projects. Nor can our assessment be limited to the context of specific projects. Now and in the future, performance will need to be embedded in a larger economic, social, and environmental context (e.g., [3] and [4]).

One widespread approach being taken to incorporate sustainability into the built environment is the use of practitioner guidelines, checklists and handbooks addressing the topic. Encompassed within these documents is a significant and growing body of knowledge with respect to applying sustainability to the built environment. The hypothesis driving the research presented in this paper is that significant gaps exist within this body of knowledge, due to varying degrees of emphasis on different phases (planning, design, construction, operation/maintenance and deconstruction) of a built facility's life cycle, and different scales (material, building system, project, community, global) of potential impacts. These gaps cannot be identified by analysis of individual publications or practitioner efforts. For example, after a brief overview of industry approaches it may appear that the current sustainability concentration of effort within the A/E/C industry has neglected the maintenance/operation phase of a facility's life cycle, concentrating mainly on the design phase of new construction. This is information which cannot be concluded or represented from analysis of a single publication.

This paper presents a classification scheme which we used to analyze sustainability knowledge contained in 26 documents addressing sustainability in the built environment. Specifically, the objectives of this analysis were threefold:

1) To determine what level of domain specificity or <u>class</u> is emphasized by this existing body of knowledge. *Is most of the information contained in the documents in the form of specifications which could be implemented directly, in the less-specific form of heuristics or rules-of-thumb, or at the most general level of guiding principles?*
2) To determine the level of product or geographic impact or <u>scale</u> emphasized by this body of knowledge. *Even though the documents target the domain of the built environment, does the knowledge apply at the level of building materials, whole systems, or at a larger level such as community or region?*
3) To determine which emphasis this body of knowledge might have on a particular facility life cycle <u>phase</u>. *Is a single life cycle phase emphasized or is the overall life cycle concept important?*

Methodology

The methodology used to accomplish the research objectives consisted of two phases: developing a database of knowledge statements from the literature about built environment sustainability, and analyzing the database to draw statistical conclusions about how that knowledge is distributed with respect to various parameters describing the built environment. The following sections describe how documents were selected to form the database, and how knowledge statements were extracted and categorized in terms of three descriptive parameters: Building Scale, Life Cycle Phase, and Class of knowledge statement. The methodology concludes with a description of the statistical methods used to analyze the database of sustainable building knowledge.

Document Selection

Generally, source documents were selected on the basis of two main attributes: availability and format. Source documents were not specifically sought out because of any particular attribute, but rather those which were easily available to the authors and generally to the A/E/C industry were used. This approach was intended to generically reflect the level of effort a practitioner might invest in obtaining information about sustainable design and construction. Source documents were also selected according to the ease with which the embedded sustainability knowledge could be extracted--most source documents included are checklists or specific guidelines. In all but three cases, source documents in an expository format were not included.

Source documents were collected and classified over a one year period. Only those source documents of a broad and generalizable nature were selected. Sources meeting specific classification designations were not sought out. Sources were collected from the World Wide Web, conferences and other publications which were phrased as checklists, handbooks, or guidelines for sustainable or green buildings. The intent of the source document collection was to offer an initial analysis in support or rejection of the hypothesis described and not to create a comprehensive collection of built environment sustainability documentation. The 26 source documents included in this study are listed with annotations in Appendix A.

A comparison of source documents by organization type, target audience and practitioner input are listed in Table 1. Table 1 also shows that a reasonable cross-representation of industry is represented throughout the source documents used for this analysis. For the final classification and assessment, source documents were divided into two groups:

1. Government/non-profit sources from any level (federal, state local, etc.)
2. Individual sources such as independent authors and private corporations

Fifteen of the documents were government or other non-profit sources while the remaining eleven were created by individuals or private corporations.

Guideline, checklist and handbook statements included in each of the source documents were entered into a database according to several factors representative of the analysis objectives. Development of the classification database will be discussed further in the next section.

Table 1 - Comparisons of Source Documents

Source Document	Source	Type	Target Audience
Ander	Individual	Checklist	Architects
Anderson	Individual	Case Study	Architects/Engineers
Atkisson & LaFond	Consultants	Checklist	Planners/Designers
City of Austin	Government	Pamphlet	Homeowners
Building Science Corporation	Consultants	Presentation	Designers/Constructors
Environmental Building News	Non-profit	Checklist	Designers/Constructors
Hardin	Individual	Guidelines	Planners
GA Office of Energy	Government	Checklist	Homeowners

Halliday/BSRIA	Government	Checklist	All Stakeholders
HOK Guidelines	Design Firm	Checklist	Designers/Constructors
HOK 10 Things	Design Firm	Checklist	Designers
IISD	Non-profit	Checklist	Planners/Owners
McDonough	Design Firm	Guidelines	Planners/Designers
NCRA GB Charette	Non-profit	Guidelines	Planners/Designers
NCRA GB Products	Non-profit	Guidelines	Designers
PCSD	Government	Checklist	Planners
Real Goods	Vendor/Educator	Case Study	Owners/Designers
Roberts	Individual	Guidelines	Engineers
Sustainability Project	Non-profit	Checklist	Homeowners
Sydney	Government	Guidelines	Planners/Designers
Tsui	Individual	Guidelines	Designers
UEA Ecopolis	Non-profit	Guidelines	Planners/Designers
UEA Specs	Non-profit	Guidelines	Planners/Designers
UEA Aesthetics	Non-profit	Guidelines	Planners/Designers
UEA Frog-stick	Non-profit	Checklist	Planners/Designers
VVWD	Government	Checklist	Designers/Constructors

Database Creation and Knowledge Statement Classification

The list of statements making up the checklist or guidelines within each source document were entered into a database for ease of analysis. Each statement was entered as an individual record categorized by *class*, *scale* of impact, and life cycle *phase*. Table 2 lists the different types of class, scale, and phase, described in the next sections of this paper. The database analyzed in this paper contained over 2000 records. All classifications were assigned by one person to increase the consistency of the classifications. Due to the nature of the listings, statements varied in length and description of practice. Key words within each of the statements were used as the descriptors over which the categorizations were made.

Table 2 - Types of Class, Scale, and Phase Designations

Analysis Factors	**Factor Designations**					
Class	Principle	Heuristic	Specification			
Scale	Material	Building System	Project	Community/ Regional	Global	
Phase	Life Cycle	Planning	Design	Construction	Operation/ Maintenance	Deconstruction/ Rehabilitation

Class Factor

Class factor dealt with the level of domain specificity of the specific statement. Statements were designated as either principles, heuristics, or specifications. Principles are the most general type of knowledge. Principles function as the fundamental axioms of sustainability and are therefore not limited to use only in the domain of the built environment, but rather apply to all domains of human activity. An example of a sustainability principle is *Conserve energ*y. There are relatively a small number of principles compared to the other class designations of heuristic and specification.

Heuristics, the second class designation, are less general than principles because they address a specific domain, in this case the built environment. Heuristics are often viewed as *rules-of-thumb*. They represent a set of operable and qualitative but often unquantitative rules which can be applied under the guidance of experts in the domain, based on their experience with similar problems. In the realm of sustainability, however, many heuristics have been derived directly from sustainability principles rather then from experience. Heuristics often serve a useful purpose in evaluation and diagnosis [5] but since they are typically suggestive rather than axiomatic, they are generally not specific enough to aid non-experts in decision-making. An example of a heuristic correlating to the Conserve energy principle is Minimize air leakage through building envelopes. This heuristic provides enough information to guide a building professional in improving the sustainability of a building, but would not be of much use to someone who was unfamiliar with techniques used to manage air leakage through building components. In addition, measuring compliance with this statement might be difficult - while we can take quantitative measures of air leakage in a building, we may never know if we have achieved minimal leakage (unless the building is hermetically sealed). No specific threshold of acceptable performance is specified.

The third class designation applied to the document source listings is the most detailed level of knowledge - the specification. Statements were classified as specifications in cases where the statement was both operable and quantifiable within the domain of the built environment. Specifications are prescriptive and measurable, and often serve as instructions for implementation of sustainability. An example of a specification following from the previous examples is "Use weather-stripping around all doors and windows". This statement is both operable (it provides specific instructions which could be understood by non-experts) and quantifiable (measuring compliance with this statement is as easy as checking to see that all building openings have been weather-stripped).

Table 3 - Class Categorization Factors for Source Document Statements

	Domain Specificity	**Evaluability**	**Operability by Non-experts**
Principle	N	N	N
Heuristic	Y	N/Y	N
Specification	Y	Y	Y

Table 3 outlines the categorization factors used for designating statements into the classes of principle, heuristic or specification. Domain specificity was dependent upon the statements relevance to the built environment. If compliance with the statement could be measured then the statement was deemed to have evaluability. The final factor was operability: could a non-specialist implement the statement?

Scale of Impact Factor
Five scale of impact designations dealt with the specific product or general geographic level at which the document source statement was targeted. The most specific designation targeted a particular *material* such as wood, concrete, or steel. The second scale designation targeted building *systems* such as HVAC, windows, superstructure, electrical, and substructure. *Project* designations were used for those statements which encompassed the operations or goals for an entire project. Examples of project statements included “Use recycled materials” and “Minimize life cycle energy use.” The next scale designation broadened the impact beyond the specific building project into the surrounding *community/regional* area. Statements such as “Integrate a regional construction site recycling program” were designated as community/regional. Scale of impact was broadened further by the last designation of *global*. The global designation, much like the principle designation used in the class factor, is the most general in application and represented statements such as minimization of resource consumption.

Life Cycle Phase Factor
Six different life cycle designations were used. There were: Whole Life Cycle, Planning, Design, Construction, Operation/Maintenance, and Deconstruction. Designations within the source documents usually further differentiated between specific life cycle phases. For example, the design phase was often broken into pre-design, design and final design. This more detailed designation was not used in our classification scheme because of increased complexity of analysis associated with large numbers of designations.

After the classification of source document statements was completed, a statistical analysis of the statements according to combinations of classifications was undertaken. The purpose of the analysis was to gain insight into which classifications are most emphasized by practitioners versus those that are currently under-emphasized.

Statistical Assessment
Analysis of variance (ANOVA) is a basic statistical technique for distinguishing differences in a response due to different classifications of several factors [6]. The ANOVA model specifies that the response values exhibit a constant error variance with a normal distribution. Our data set (discussed below) has many zero entries resulting in a very high peak at zero in the distribution and larger error variance surrounding higher-valued fractions. In cases of nonconstant error variance and nonnormality, a transformation of the response values may rectify the problem. For our data, we transformed our response by calculating the square root of the response values. This stabilized the error variance, but only improved the nonnormality slightly (in that the distribution of the square root values was more normally distributed). The ANOVA calculations are robust against departures from normality.

Our objective was to focus on which particular combinations of class/phase/scale designations resulted in a significantly larger (or smaller) fraction of entries. Since typical multiple comparisons are sensitive to nonnormality, we chose to limit our comparisons to those combinations of class/phase/scale that had at least one nonzero response value (for either government or individual sources). This effectively removed a large enough portion of zeroes from our data set so that the square root transformation successfully achieved both a constant error variance and a normal distribution.

The Tukey multiple comparison procedure was used to distinguish the combinations of class/phase/scale designations. This procedure compares all possible pairs of class/phase/scale combinations and determines whether each pair is statistically equivalent or statistically different. Statistical equivalence essentially states that the two class/phase/scale combinations in the pair appear to achieve the same response value within the error variability of the data set. The results of the Tukey procedure depend on a family error rate which specifies the statistical confidence of our equivalence and difference determinations. An error rate of 10% specifies 90% confidence in the simultaneous correctness of our Tukey pairwise comparisons.

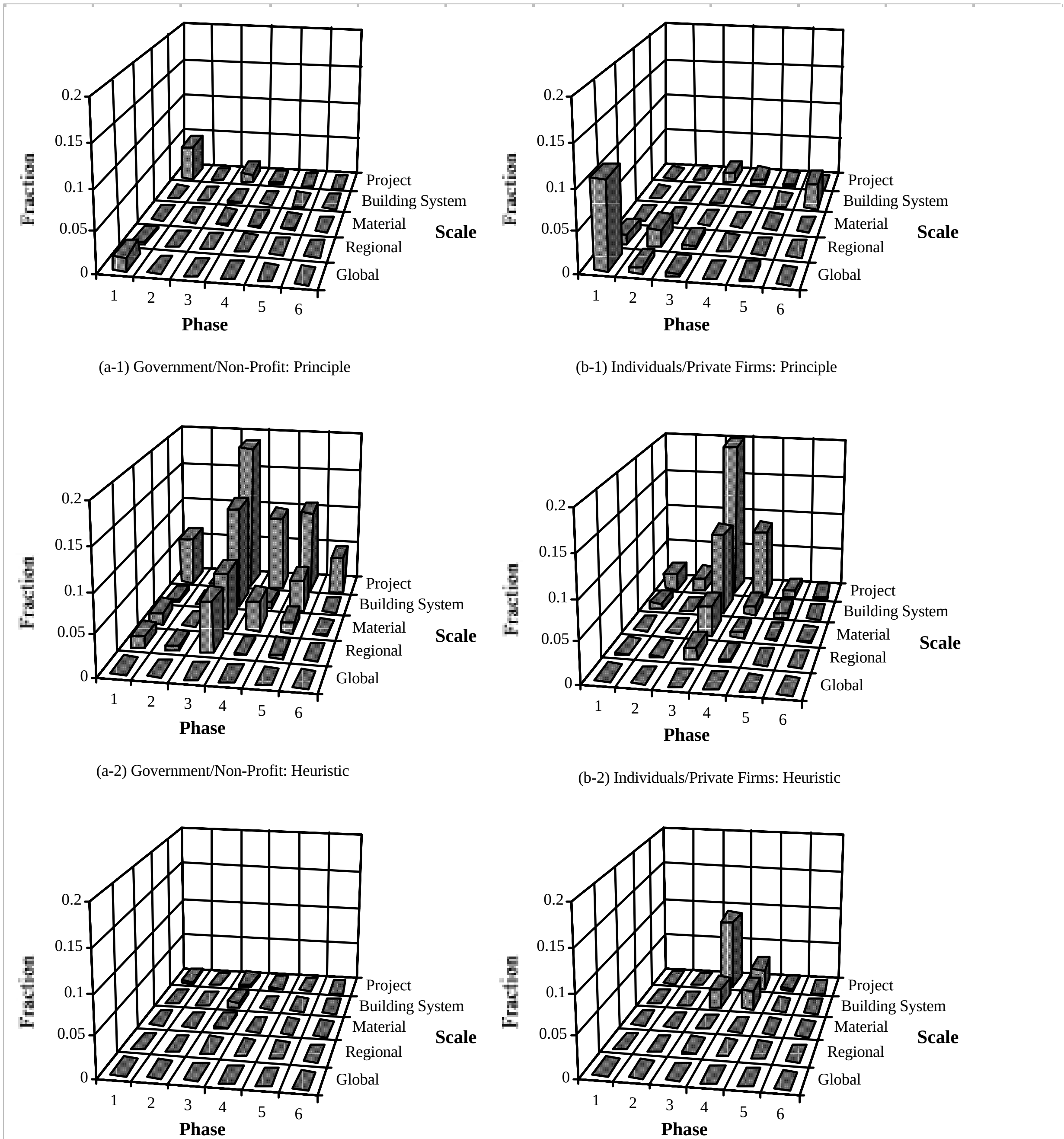
Finally, a distribution-free statistical test of hypotheses [7] was conducted to further support the results of the Tukey procedure. This statistical test compares the proportion of counts between two different categories and determines whether or not the data support the hypothesis that their respective proportions are different. The unknown true proportions are estimated by maximum likelihood estimation, and decision rule of the test is based on a chi-square test statistic.

Analysis and Results - The State of A/E/C Sustainability Knowledge

Associated with each database entry are a source document type (government/non-profit or individual/private) and designations of class, scale, and phase (as given in Table 2). For each combination of source type and class/scale/phase designations, the number of database entries were counted. This collection of counts comprised the initial data set. Since database entries from government sources numbered 1274 while those for individual sources numbered only 839, each count was divided by its corresponding source type total. These fractions now represented the proportion of database entries, within a source document type, for each class/scale/phase designation combination. Thus, the response for our statistical analysis is the fraction of database entries.

Figure 1 presents these fractions as our response values. The different charts are separated by source type and class designation while scale and phase designations are represented within a chart. The different phases (numbered 1 to 6) remain in the order given in Table 2 since this represents a natural ordering of the building process. What is immediately apparent from Figure 1 is that there are only a few fractions that are significantly greater than zero. In fact, there are 107 fractions (out of 180) that are exactly zero.

The square root transformation on the fraction of database entries was used to stabilize the error variance, and the resulting ANOVA table is shown in Table 4.



(a-1) Government/Non-Profit: Principle

(b-1) Individuals/Private Firms: Principle

(a-2) Government/Non-Profit: Heuristic

(b-2) Individuals/Private Firms: Heuristic

(a-3) Government/Non-Profit: Specification

(b-3) Individuals/Private Firms: Specification

Figure 1 - The fraction of database entries. The charts are seperated by source document type and class designation. Within each chart phase designations 1 through 6 are life cycle, planning, design, construction, operation, and deconstruction.

The p-values for the F-tests indicate that the different designations of class/phase/scale do account for differences in the fraction of database entries. However, the different source document types do not affect the fractions. All two-factor interactions are statistically significant, but the three-factor interaction is not. This means that, for example, how the fraction of entries changes for the different classes depends on which phase is associated with these entries.

Table 4 - Analysis of Variance for the square root of fraction.

Source	DF	SS	MS	F	P
Block	1	0.000011	0.000011	0.00	0.950
Class	2	0.215912	0.107956	39.84	0.000
Phase	5	0.217765	0.043553	16.07	0.000
Scale	4	0.210131	0.052533	19.38	0.000
Class*Phase	10	0.175782	0.017578	6.49	0.000
Class*Scale	8	0.195028	0.024378	9.00	0.000
Phase*Scale	20	0.165457	0.008273	3.05	0.000
Class*Phase*Scale	40	0.112177	0.002804	1.03	0.436
Error	89	0.241194	0.002710		
Total	179	1.533456			

Using the Tukey multiple comparisons procedure with a 10% family error rate, we were able to distinguish two combinations class/phase/scale as having significantly larger fractions of entries:

(1) Heuristic Class, Project Scale, Design Phase;
(2) Heuristic Class, System Scale, Design Phase.

A third combination was significantly larger with a 12% family error rate:

(3) Heuristic Class, Project Scale, Construction Phase.

The remaining combinations could not be distinguished as having statistically different fractions from each other. Note the presence of the heuristic class in all three combinations class/phase/scale and the presence of the project scale and the design phase each in two out of three.

The final statistical analysis we conducted considered, within the heuristic class, the emphasis of the project scale over other scale designations and the design phase over other phase designations. For the distribution-free statistical test for the project scale designation, the four scale designations material, building system, community/regional, and global were combined into one category, and, within the heuristic class, the proportion of database entries for this combined category was compared to that of the project scale designation. Similarly, for the design phase designation, the five phases life cycle, planning, construction, maintenance, and deconstruction were combined into one category, and within the heuristic class, the proportion for the combined category was compared to that of the design phase. The result of the tests are:

- the proportion of database entries designated as the project scale within the heuristic class clearly dominates the combined proportion of all other scale designations, and

- the proportion of database entries designated as the design phase within the heuristic class clearly dominates the combined proportion of all other phase designations.

While the conclusions of the Tukey multiple comparisons procedure establishes the dominance of the heuristic class, the conclusions of the distribution-free test emphasize the dominance of the project scale designation and the design phase designation within the heuristic class.

Discussion and Conclusion - The Concept of Sustainability and the Role of Practitioners

In summarizing the results of the ANOVA statistical analysis there are three main points. First, given the data analyzed and a 12% family error rate there are only three statistically significant different class/phase/scale designations out of a possible 90 combinations. This means that we have significant knowledge about built environment sustainability at the heuristic level for projects in the design and construction phases, and at the building systems scale for the design phase of the building life cycle. Secondly, upon further examination of those three significant class/phase/scale designations there are several similarities which become apparent. The heuristic class is present in all three, and both project scale and design phase are present in two out of the three. Thirdly, within the heuristic class the emphasis of project scale and design phase dominates the classification of knowledge.

From these conclusions, we can see that there are significant opportunities for development of additional knowledge at the principle and specification levels for all phases of the life cycle and all scales of the built environment. There are also significant opportunities to develop additional heuristic knowledge for phases of the life cycle before and after design and construction. Based on the distribution of knowledge across life cycle phases and built environment scales, the potential for future research to generate new knowledge about built environment sustainability is great.

Our analysis of attempts to incorporate sustainability knowledge into the built environment shows that practitioners are concentrating on the design phase of specific projects. Although sustainability inherently requires innovative life cycle solutions, perhaps our knowledge level as an industry has not yet developed sufficiently to allow for this broader perspective. We hope that the meta-analysis of sustainability knowledge presented in this paper will help to move the evolution of sustainability knowledge in this direction.

With the rapid pace of new knowledge being generated in the area of sustainability for the built environment, updating the database of sustainability knowledge is an exponentially-growing challenge. Our limited selection of document sources and uncomplex classification scheme may be quickly outpaced by the growth of knowledge in the industry. However, the intent of this classification and assessment exercise was to serve as a beginning point of understanding about the shape sustainability-related knowledge is taking in the A/E/C industry. We hope that the general conclusions derived from this type of analysis will serve as a catalyst toward filling the knowledge gaps identified in the application of sustainability to the built environment.

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Appendix A - Source Document Annotation Listing

Ander, Gregg D. (1994). *A Check List for Sustainable Architectural Design, Earthword*, Sustainable Architecture, 1(5), 52-53.

> This source developed a checklist for environmental accounting as part of an interrelated approach to sustainable design. It was based on AIAís standard contract protocol for project stages, and is meant to apply during the early stages of a standard linear architectural design process. List items were typed in verbatim - no rewording necessary.

Anderson, Abba. (1994). *Advances in Texas: Sustainability gets 'Green Lite', Earthword*, Sustainable Architecture, 1(5), 50-51

> In this paper, the development of the State Insurance Building in Austin, TX was used as a case study to develop a revised set of state's guidelines for architectural and engineering firms. The design for the facility was developed by Pliny Fisk, of the Center for Maximum Potential Building Systems. List items were paraphrased from the text of the article, which was in narrative form.

AtKisson, A., and LaFond, M. (1994*). Assessing Sustainability Projects: A Prototype Rating System for Comparative Evaluation.* AtKisson & Associates, Inc. Sustainability Development Series, Paper 1.

> This information was taken from a white paper produced by AtKisson & Associates. It presents a checklist for evaluating projects on a somewhat subjective but nonetheless quantitative basis, with three general classes or scales of evaluation: sustainability,

institutionalization, and comprehensiveness and integration. The authors' definitions of each scale are included and noted as such. Some rewording was necessary to put each statement into prescriptive form.

City of Austin Environmental & Conservation Services Department. (1995). *Residential Green Building Program: A Sustainable Approach*. Informational Pamphlet.

List items for this source were taken from several lists of heuristics and principles interspersed throughout the brochure, developed by the City of Austin, TX Environmental and Conservation Services Department. See also Sustainable Building Handbook on the Web by the same department. List items typed in verbatim.

Building Science Corporation. (1996). *Building America: A Systems Approach to Sustainable Design.* Presentation to the 1996 Southeastern Green Building Conference, Wilmington, NC, Oct. 5-7.

This material was taken from a presentation packet prepared by Building Science Corporation of Westford, MA, which presented several residential case studies to substantiate and illustrate their sustainable design framework. Some items had to be reworded slightly to fit into prescriptive form. Material in the packet ranges from summary slides, to textual lists of heuristics and specifications, to examples showing how specification values are calculated, to framing details for improved construction of houses.

EBN (1994). *Checklist for Environmentally Sustainable Design and Construction. Environmental Building News*.

This material came from a flyer picked up at the 1994 Sustainable Construction Conference in Tampa, FL. The issue of EBN in which it was printed is unknown, as well as the author. Material is organized into five categories: design, siting, materials, equipment, and job site. In each category, there are two levels of specificity - a high-level heuristic summary statement, and an accompanying set of specifications or lower-level heuristics. List items were typed in verbatim - no rewording necessary.

Hardin, Garrett. (1993). *Living Within Limits: Ecology Economics, and Population Taboos.* Oxford University Press, New York.

This information was taken from the last part of chapter 27 in Hardin's book. It summarizes the various conclusions he draws over the course of the book. Other *laws* have been taken from Chapter 19, describing major default positions of human biology. Statements have been entered verbatim, and are, for the most part, principles for human sustainability. Further reading of the book may be needed for the reader to understand the background of some of the statements. Subreferenced quotes from Commoner 1971 and Ehrlich & Holdren 1971 have been included (see above references).

Georgia Office of Energy Resources. (1994). Around the House: Energy Saving Ideas. Informational Pamphlet. 2080 Equitable Building, 100 Peachtree St., NW, Atlanta, GA 30303.

This source is an informational consumer-level pamphlet which provides suggestions for saving energy in residential operations. It was supported by US DOE Grant No. DE-FG44-77CS60212. List items were typed in verbatim - no rewording necessary.

Halliday, S.P. (1994). *Environmental Code of Practice for Buildings and their Services*. The Building Services Research and Information Association, Bracknell, Berkshire, UK.

This source has generated a qualitative environmental code of practice targeted at clients, architects, project managers, estimators, facilities staff, and building services engineers. It provides by facility life-cycle phase. The guide was developed as the final output of a research project whose objective was

"to identify cost-effective approaches to reducing the adverse environmental impact of the built environment and to describe and quantify benefits." (p. 1). List items were typed in verbatim - no rewording necessary.

HOK. (1994). *Sustainable Design Guidelines*. HOK, Inc.

This source developed a checklist for sustainable design to serve as a guideline for HOK's design practices. List items were typed in virtually verbatim - no rewording necessary.

HOK. (1995). *10 Simple Things You Can Do*. HOK, Inc.

This source developed a "10 Simple Things You Can Do" checklist for sustainable design to serve as a guideline for HOK's design practices. List items were typed in virtually verbatim - no rewording necessary.

IISD. (1995). *Canadian Choices for Transitions to Sustainability*. Ottawa : Projet de societe. Final draft. May. Chapter 1. URL: http://iisd1.iisd.ca/worldsd/canada/projet/choices/box5.html and
URL: http://iisd1.iisd.ca/worldsd/canada/projet/choices/box4.html.

This information was taken from two summary boxes on the IISD web page, based on the document *Canadian Choices for Transitions to Sustainability*. It describes sustainable development principles of the Projet de sociÈtÈ. List items from Box 5 were typed in verbatim - no rewording necessary. List items from Box 4 were reworded into prescriptive statements.

McDonough, William, Architects. (1992). *The Hannover Principles*. University of Virginia Architecture Publications.

These principles are known as the Hannover Principles, and were developed by William McDonough to serve as sustainable design guidelines for the World Fair development in Hannover, Germany. They have been described as follows: "The Hannover Principles should be seen as a living document committed to the transformation and growth in the understanding of our interdependence with nature, so that they may adapt as our knowledge of the world evolves." List items were typed in verbatim - no rewording necessary. Some multiple-sentence list items were split as appropriate.

North Carolina Recycling Association. (1994). *North Carolina Green Building Charette: Final Report*. North Carolina Recycling Association, Raleigh, NC. April 29-30.

These list items came from a report produced by the NCRA as a result of conducting a design charette to get ideas and discuss issues for their new headquarters building. This report is also available on the Web at http://www.recycle.net/recycle/ncra/charette. List items were reworded slightly to generalize as appropriate, since all items were targeted specifically at the new NCRA headquarters building.

North Carolina Recycling Association (1997). *Green Building Products Directory*. http://www.recycle.net/recycle/ncra/GBDWelc.html.

These list items came from a section of this web page called "Environmental Considerations of Product Types", divided by CSI division. Items were entered verbatim, for the most part - no rewording necessary. Narrative introductory sections were omitted.

President's Council for Sustainable Development. (1994). *Principles of Sustainable Development*..

These principles came from a draft of a President's Council task force effort to define and operationalize sustainable development as it might affect US policy. List items were typed in verbatim.

Real Goods. (1996). *The Hopland Solar Living Center: A Model of Sustainable Development*. Brochure.

This information was taken from a promotional brochure describing the design, construction, and guiding principles of the Real Goods Solar Living Center in Hopland, CA. List items were typed in verbatim - no rewording necessary.

Roberts, D.V. (1996). *History of Engineering....*, 8th Annual Stanley D. Wilson Memorial Lecture, University of Washington Department of Civil and Environmental Engineering, May 2.

This information was taken from a videotape of a lecture given by Don V. Roberts of the something on Sustainable Development. The lecture was given at the University of Washington. Some heuristics were taken directly from slides, while others were taken verbatim or slightly reworded from his speech.

Sustainability Project. (1996*). What can you do to make your home and garden more sustainable?* Informational pamphlet. 229 E. Victoria St., Santa Barbara, CA 93101.

This material was typed in verbatim from a flyer obtained at the 1996 Sustainable Building Conference in Santa Barbara. The flyer contains a list of suggestions for homeowners to make their homes and gardens more sustainable.

Sydney. (1996). *Olympic Village Design Brief*. Part C, Design Guidelines. Sydney, Australia.

This information was taken from the design guidelines for the Olympic Village to be constructed for the 2000 Olympic Games in Sydney, Australia. The objective of the guidelines are stated as follows: “To lead in the area of Ecologically Sustainable Development, and demonstrate its application.” List items were reworded as necessary to put them into prescriptive form. Some spellings were converted to American English to facilitate database integration. Complete citation unknown.

Tsui, Eugene. (1996). *Principles of Evolutionary Architecture.* TDR Inc. http://www.TDRInc.com/

This information was taken from the TDRInc. web page, which describes the design philosophy, projects, etc. of TDR and its founder, Eugene Tsui. These principles are meant to reflect Tsui’s philosophy of evolutionary architecture. TDR undertakes facility architecture, design and construction, as well as product design. Basic principles were typed in verbatim - no rewording necessary. Some items were split as appropriate, or reworded to fit prescriptive form.

Urban Ecology Australia. (1995). *Ecopolis Development Principles* http://www.eastend.com.au/~ecology/ecocity/guidelines.principles.html

this information was taken from a web page developed by Urban Ecology Australia, describing Ecopolis Development Principles for sustainability. The objective and purpose of the page is to provide guidelines for human settlements in which “built form and natural processes are functionally integrated to satisfy human needs as part of the dynamic ecological balance of living systems.” List items were typed in verbatim - no rewording necessary.

Urban Ecology Australia. (1995). *Some Specific Aspects of Ecological Development.* http://www.eastend.com.au/~ecology/ecocity/guidelines/specs.html.

This information was taken from a web page developed by Urban Ecology Australia, describing Ecological Development Principles for sustainability. The objective and purpose of the page is to provide a prescriptive framework for ecological urban development projects, with specific guidelines for buildings, water supply, energy, etc. List items were developed by condensing categories and descriptions found on the web page and putting them into prescriptive form.

Urban Ecology Australia. (1995). *The Aesthetics of Ecological Architecture.* http://www.eastend.com.au/~ecology/ecocity/guidelines/aesthetics.html.

This information was taken from a web page developed by Urban Ecology Australia, making reference to the “Ten Principles” of architecture penned by Prince Charles which "have some relevance to the creation of an integrated human settlement in balance with human social needs, cultural aspirations, and the biosphere." List items were reworded somewhat, to incorporate both Prince Charles' original text and the subsequent explanations and descriptions by UEA.

Urban Ecology Australia. (1995). *Urban Ecology Checklist: The 'Frog-stick'*. http://www.eastend.com.au/~ecology/ecocity/guidelines/frogstick.html.

This information was taken from a web page developed by Urban Ecology Australia, describing a measuring tool for evaluating urban ecology, nicknamed the Frog-stick. The checklist is based on where the item being evaluated falls on a scale between unsustainability and sustainability. Charts are shown on the original document which provide a framework for evaluating specific indicators/attributes. Rewording was necessary to put concepts into prescriptive sentence form. The objective and purpose of the Frog-stick is described as follows: "...to identify those impacts of the conventional built environment which separate it from the natural environment, or 'wilderness'. With this 'measuring stick' one may begin to assess the ecological impact of urbanisation."

VVWD. (1994). *Victor Valley Water District Administration Facility, Earthword,* Sustainable Architecture, 1(5), 54.

This information was taken from a short case study following the Anders article. It describes design and construction measures taken in the Victor Valley Water District Administration Facility, which resulted in a facility that outperformed the California State Energy Efficiency Standards by 66%. List items were typed in verbatim - no rewording necessary.