

# **A PARAMETRIC REVIEW OF THE BUILT ENVIRONMENT SUSTAINABILITY LITERATURE**

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## **Abstract**

The literature on built environment sustainability has grown dramatically in the past ten years. Despite the proliferation of literature, there is still no consensus on how to comprehensively and uniformly define the concept of sustainability as it pertains to the built environment, nor is there consensus on what aspects of the built environment should be considered in evaluating the sustainability of a built facility. This paper, through an evaluation of selected sources from the sustainability literature, takes a first step at systematically identifying what parameters of both the built environment and the concept of sustainability are emphasized in the existing literature on the topic. The outcome is a set of parameters that can be used in future research to begin to uniformly and comprehensively define sustainability as it applies to built facilities, using techniques such as concept mapping, content analysis, dendograms, and other established research methods.

## **Keywords**

Sustainability, built environment, definition, parametric, concept mapping, literature evaluation, models and frameworks, guidelines and heuristics, assessment and evaluation tools, resource guides

## **Biographical Notes**

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Dr. Annie Pearce is a Research Engineer and Director of the Sustainable Facilities and Infrastructure Program at the Georgia Tech Research Institute. Dr. Pearce's research focuses on measuring the sustainability of built facilities and prioritizing facility improvement options to increase built environment sustainability. Dr. Pearce's work at Georgia Tech includes shared appointments with the School of Civil and Environmental Engineering and the College of Architecture, where she teaches courses on Green Building, Environmentally Conscious Design and Construction, and Sustainable Design. She is a designer and trainer for Georgia Tech's continuing education certificate series in Sustainable Facilities and Infrastructure, and has done sustainability training for owner, design, and construction firms on local, national, and international scales. Dr. Pearce's research includes work in the areas of sustainability knowledge characterization, decision making, facility and materials assessment, data mining, and teaching and learning.

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Dr. Jorge Vanegas is the Fred and Teresa Estrada Professor of Civil Engineering at Georgia Tech. In this capacity, he is responsible for developing a focused, multidisciplinary, and self-sustaining institutional infrastructure for sustainable affordable housing education, research, and outreach for the U.S. and the Americas. Dr. Vanegas's primary areas of research, interests, and publications include: (1) advanced strategies and technologies for sustainable land development, planning, design, and construction of sustainable facilities and civil infrastructure systems; (2) design/construction integration and the development and rehabilitation of facilities and civil infrastructure systems; (3) advanced strategies, tools, and methods for effective management of capital projects; (4) constructability programs and advanced technologies for modularization and pre-assembly; and (5) undergraduate, graduate, and professional continuing education curricula development. Dr. Vanegas holds a joint appointment with the College of Architecture at Georgia Tech, where he serves as the co-director of Tech's Construction Resources Center.

## **Introduction**

The concept of sustainability with respect to the built environment is not new; this concept evolved from theory of appropriate technology and environmental awareness of the 1970's, and has taken on increased importance in the subsequent three decades as the impacts of human activity on a planetary scale become apparent. Despite the evolutionary history of the concept, the range of perspectives on how sustainability should be defined and operationalized with respect to the built environment is extremely broad and sometimes conflicting. This paper establishes a framework for classifying resources related to built environment sustainability, and reviews a cross-section of existing literature in terms of parameters considered by each author

to be important in defining what sustainability means for built facilities. The purpose of the paper is to establish a point of departure for ongoing built environment sustainability research by illustrating the diversity and highlighting similarities among implicit theories of built facility sustainability represented in existing work. The outcome of the paper is a set of parameters used in the literature to characterize built environment sustainability that can be used as a basis for further articulating the concept in future research and application.

### **Strategy for Analyzing the Literature**

The purposes of the research described in this paper were three-fold: 1) to initiate the development of a set of variables that can comprehensively and uniformly define built environment sustainability; 2) to highlight differences in emphasis on specific variables in different sources in the literature; and 3) to establish a point of departure for future research to develop a parametric representation of sustainability for the built environment using established methods such as concept mapping, content analysis, or dendograms. The following subsections describe the research approach used to achieve these goals.

### ***Source Selection, Classification, and Characterization***

The first task of the research was to identify a set of references for analysis that provide a representative cross-section of the built environment sustainability literature. Toward this end, forty-one references were hand-selected by the researchers to provide a spectrum of perspectives from multiple sources and serving multiple functions. To determine representative literature by function, sources were classified into five basic categories of functionality: general references, models and frameworks; guidelines and heuristics; assessment and evaluation tools; and resource guides. Table 1 lists the references selected for analysis. Each of these categories is described in further detail in the sections corresponding to each category. Authors of selected references included academics, government agencies, researchers, and practitioners ranging from architects to builders.

Three sources represented overviews or syntheses of specific segments of the literature [1] and thus offered perspectives combined from multiple sources. The first two of these three sources provide an overview of built environment sustainability initiatives in multiple countries, while the third examines initiatives in six different cities across the United States. All told, perspectives from 15 different countries were included in this study, although primary references are mostly from the United States, Great Britain, and Australia. Target audiences of the references included in this study range from the lay homeowner to building professional, with the entire spectrum of stakeholders including government officials, planners, policy makers, facility owners and managers, and academic researchers.

### ***Identification of Variables***

After references had been selected for analysis, the primary issue in analyzing the literature was how the authors defined the subject of sustainability, reflected by the choice of

variables or parameters included or used to classify elements in their work. A secondary issue was how the authors conceptualized the built environment in terms of facility-related variables. The reason for identifying these variables was to permit comparison of the subjects each author explicitly or implicitly used to define both sustainability and the built environment. Identifying the variables also permits inferences about what each author felt were the critical facility drivers of sustainability, and illustrates the divergence among authors with respect to their implicit theories of built facility sustainability.

Each source was reviewed to identify variables that defined how the authors characterized the relationship between sustainability and the built environment. Keywords were identified as variables in one of three primary ways:

- From table, diagrams or figure labels, if the author(s) provided graphical or tabular summaries of their conceptual framework or findings;
- From headings and subheadings used in the work; or
- From bullet lists within the work that summarized issues considered or important concepts.

The goal was to identify on the order of five to twenty five keywords per source that captured the essence of how the author(s) conceptualized built environment sustainability. Additional parsing of the text of each resource could provide a much more vast network of relevant keywords [2], but only the top level hierarchy of variables was identified for this research, since the goal was to examine broad attributes of built environment sustainability. Where it was apparent in the organization of the work, up to two levels of hierarchical organization of variables were captured as reflected by indentation and Italics in the tables of findings.

### ***Summary of Identified Variables***

After variables from each source had been identified, variables were placed into tables in chronological order according to category of source: heuristics and guidelines, resource guides, models and frameworks, assessment and evaluation tools, and general references. This tabular representation of findings permits visual comparison of the differences, similarities, and gaps across sources for each class. The next five sections of the paper provide an overview of selected sources from the built facility sustainability literature within each of these classes, highlight the sustainability and built environment variables considered to be important by each source, and discuss the limitations and opportunities present within each class of literature.

### **General References**

The first category of literature examined in this work is general references, defined as references consisting of material that is intended to serve more than one purpose. For example, one reference in this class includes both heuristics for material specification and a resource guide to green materials and organizations [3]. Other references in this class provide extremely broad coverage of topics or are intended to introduce the reader to built environment sustainability in general, and thus do not fit within one of the other functional classes.

### ***Synthesis of Existing General References***

Four sources from the literature were selected to represent a cross-section of existing general references on built environment sustainability. References in this category can be

distinguished by the scale of the built environment on which they focus: the first two references focus on whole buildings and developments, while the third and fourth references focus primarily on materials, building systems, and components.

The sources also differ significantly in their target audiences. The first source is written at a level appropriate for the lay audience, and is intended to introduce its readers to the broad spectrum of possibilities for improving built environment sustainability on a residential scale [4]. In contrast, Langston's book [5] focuses on a much more academic audience: the chapters of this book are targeted at some of the more theoretical aspects of sustainable construction such as environmental accounting, policy, cost-benefit analysis, and the general principles of sustainable development. The third and fourth sources are more targeted to practitioners. The *Green Building Handbook* [6] provides a broad range of material organized around building materials and systems, and provides practitioners with summarized information that is useful in making choices among systems without going into depth with detailed numerical data. From a different angle, *Green Building Materials* provides practical information for practicing designers, including model specification language, comprehensive lists of relevant U.S. regulations and legislation that influence material selection, and extensive directories of organizations and sources for more information [7].

### **Limitations and Opportunities**

The general references selected for analysis in this work provide a cross-section of available work in terms of target audience, built environment scale, and topical coverage. Table 2 shows the built environment sustainability variables identified in the analysis of this segment of the literature. Within this spectrum, opportunities exist to develop resources that will fill in gaps not covered at present by general references. For example, the topics covered in Langston's work on *Sustainable Practices* should be of interest to the lay audience, but are presented at a technical level beyond many nonprofessional readers' level of comprehension. Additional work is needed to explain these important concepts at a level more similar to Barnett & Browning's *Primer*, so that lay audiences can reach a better understanding of the importance of sustainable construction. Likewise, gaps still exist in the resources available to practitioners to support their comprehension and decision making for project sustainability. Additional resources such as the model specification language found in Spiegel & Meadows' *Green Building Materials* and the quick reference comparison of impacts of building systems found in the *Green Building Handbook* should be developed to apply to other contexts, scales, and types of built facility construction.

### **Models and Frameworks**

Moving to the theory-based segment of the literature, the next category includes existing models and frameworks of built environment sustainability. In the context of this analysis, models are defined as abstract representations of the real world, specifically of built environment sustainability. Each of the models analyzed represents various parameters and objectives of sustainability, along with different sets of built environment variables considered important by the

authors for sustainability. The term *framework* in this context refers to prescriptive or process models, specifically those abstract or simplified representations of real world processes that illustrate how sustainability should be achieved for the built environment.

### ***Synthesis of Existing Models and Frameworks***

Six sources from the literature were selected to represent a cross-section of existing models and frameworks. The model and framework literature is characterized by a split between reductionist approaches vs. holistic, systems approaches, and the first four sources were selected to equally represent each side [8]. The fifth framework [9] was included since it addresses sustainability from an organizational, rather than physical facility, point of view, and is prescriptive rather than evaluative in nature. The sixth framework [10] is a compilation of sustainability perspectives from fourteen different countries, and as such, represents a composite perspective of sustainability on an international level.

With one exception, these models and frameworks were developed independently of one another, representing the fragmentation that is characteristic of applied research in sustainability to date. The first two sources [11] are sequential first approaches to operationalizing sustainability in the context of facility construction, and represent a reductionist view of sustainability in their checklist approach to selecting indicators. Neither of these conceptual frameworks was developed to the point of being functional as a predictive or evaluative model of the sustainability of facilities. Both models help practitioners to understand what important variables of sustainability might be for built facilities, but neither is based on a rigorous operationalization of the concept.

The third and fourth sources are systems-based models of built facilities and identify properties and characteristics of facility systems on a holistic level that are important for classifying and evaluating their impacts on the environment [12]. While both of these sources mention the concept of sustainability, neither model is explicitly billed as being a model of facility sustainability. Lyle's model illustrates the results of applying "regenerative design" to the process of creating built facilities and communities, and shows how this paradigm of design can help technological systems more closely mimic the behavior of natural ecosystems. Yeang's model of "ecological design" incorporates a systems representation of built facilities and identifies the flows of matter, energy, and information into, out of, and within facility systems as the critical driver of ecological impact. Both of these models provide significantly more insight into how facilities affect their contexts, but neither provides the capacity to evaluate or predict how changes will impact the sustainability of a facility system.

The fifth model, a "framework for the attainment of sustainable construction", differs from the rest of the models in that it targets sustainable construction from an organizational, rather than a physical facility, point of view. This framework was conceived as a process model for organizations to implement "integrated environmental management" of their construction projects [13]. This prescriptive model is targeted to policy makers and managers in construction organizations.

The sixth model considered in the analysis was derived from a combined analysis of sustainable building practices from fourteen different countries around the world [14]. This

conceptual framework was based on identifying issues important for built environment sustainability in the reports of fourteen individual countries, and combining those issues into a taxonomy of considerations for sustainable building on an international scale.

### ***Limitations and Opportunities***

The review of models and frameworks of built environment sustainability from the literature shows that disparities exist in terms of both the variables included for consideration and the intended applications of the work. Table 3 provides a summary of the information unearthed in the analysis of the models and frameworks. One significant challenge apparent from examination of the table is the wide disparity in what variables are considered important for defining sustainability. While the variables included for the built environment may legitimately vary based on the phase of problem solving being addressed and the scale and type of facility being analyzed, the lack of consensus among models purporting to solve the same problem is further evidence of the need for alignment of the variables into a unified construct of sustainability.

Other weaknesses of existing models of built environment sustainability include insensitivity to contextual factors of built environment systems and lack of a mechanism for evaluating sustainability in the context of built environment systems. Many of the researchers and practitioners whose models were examined here do not provide examples of how their work could be applied to real built environment systems. Since many of the models are presented at a conceptual level, testing and validation is nearly impossible, and has not been conducted by the model developers. While these models are a necessary step in the evolution of built environment sustainability knowledge, they have limited usefulness for identifying, prioritizing, and solving problems in practice.

### **Heuristics and Guidelines**

The next category of literature is the body of work comprised of heuristics or guidelines for planning, designing, constructing, operating, maintaining, and ending the life cycle of built facilities. Literature in this category represents the body of knowledge created and tapped by building practitioners in striving to achieve sustainability in professional practice. As such, it is the most practical sector of knowledge in the sustainability-related building literature, and is a starting point for evolution of knowledge.

### ***Attributes of Knowledge Statements***

The growing body of practical knowledge statements about sustainable design and construction can be represented on three parallel levels of specificity: principles, heuristics, and specifications (Figure 1 [15]). Principles are the most general type of knowledge, and are defined as inoperative statements that together form a global set of objectives to define sustainability. These first principles comprise the fundamental axioms of sustainability theory and are therefore not limited to use only in the domain of the built environment, but rather apply to all

domains of human activity. There are a relatively small number of principles compared to the other class categorizations of heuristic and specification. Examples of principles from reviewed sources include:

- Practice pollution prevention. [16]
- Reduce life cycle energy consumption. [17]
- Reduce, reuse, or recycle waste. [18]

Heuristics, the second class categorization, are less general than principles because they address a specific domain, in this case the built environment. Heuristics are often referred to as 'rules-of-thumb'. They represent a set of operable and qualitative but often unquantitative rules that can be applied under the guidance of experts in the domain, based on training or past experience.

In the realm of sustainability, many heuristics have been derived directly from sustainability principles rather than from trial and error. Heuristics often serve a useful purpose in assessment and diagnosis [19] 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 one can take quantitative measures of air leakage in a building, one may never know if minimal leakage has been achieved. No specific threshold of acceptable performance is specified. Examples of heuristics from reviewed sources include:

- Provide ecologically sound and healthy building materials. [20]
- Assess external microclimate including sun paths, seasonal temperatures, local wind and rainfall patterns. [21]
- Integrate passive solar heating with daylighting design. [22]
- Study regional impacts of proposed development, such as transportation, water quality and flooding, ecosystems, and wildlife habitats. [23]
- Select low-emitting, environmentally friendly cleaning agents for use in regular maintenance. [24]
- Increase efficiency of irrigation with controllers and sensors. [25]

The third class of sustainability guidelines is the most detailed level of knowledge - the specification. Statements can be classified as specifications in cases where the statement is 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). Additional examples of specifications from the reviewed sources include:

- Exceed ASHRAE/IES standard 90.1-1989 by 30%. [26]
- Use life cycle costing with 25-year life cycle to evaluate cost beneficial options. [27]
- Increase average building durability from 40 to 100 years. [28]
- Use not more than two incandescent luminaires in any one interior. [29]
- The maximum distance, in plan, between a luminaire and its switch should not exceed three times the height of the luminaire above the floor. [30]
- Recommend nonsmoking buildings. [31]
- Amend soil in planting areas according to professional advice. [32]

Table 4 [33] summarizes the factors used for categorization of statements into the classes of principle, heuristic or specification. Domain specificity is dependent upon the statement's relevance to the built environment. If compliance with the statement can be measured, then the statement can be deemed to have evaluability. The final factor is operability, determined by answering the following question: can a non-specialist implement the statement and/or determine when it has been achieved?

### ***Synthesis of Existing Heuristics and Guidelines***

From the many available sets of heuristics and guidelines developed for built environment sustainability, ten sets were analyzed in detail in this analysis. The ten sets of heuristics and guidelines were selected to address multiple phases of the facility life cycle: two of the sets of guidelines were developed to assist in designing sustainable facilities [34]; two were developed to facilitate sustainable construction [35]; and six provide guidance over multiple phases of the facility life cycle [36]. Of the comprehensive guidelines covering multiple life cycle phases, two are unique in providing guidance in electronic form. *Green Building Advisor* [37] is a commercial software package developed in the United States that uses a knowledge-based system to identify relevant strategies based on basic project parameters entered by the user. The *Sustainable Building Sourcebook* [38] is an evolving web-based reference that incorporates a variety of information relating to sustainable building technologies and strategies, including ratings on how difficult each may be to implement and contact information for qualified contractors, designers, and suppliers in the Austin, TX region. It is part of a larger web site that provides links to a directory of sustainable building professionals, an events calendar, and an online bookstore for sustainable building references.

### ***Limitations and Opportunities***

The review of guidelines for built environment sustainability from the literature shows that significant disparities exist in terms of the variables included for consideration, as well as with respect to the nonuniform emphasis on the design phase of the built environment life cycle.

Separate analysis supports the conclusion of uneven coverage of both life cycle phase and scale in terms of sustainable building knowledge [39]. In Figure 2 [40], the phase designations 2-6 correspond to facility life cycle phases of Planning, Design, Construction, Operation/Maintenance, and Deconstruction/Rehabilitation. Phase 1 represents heuristics that were applicable to all life cycle phases. The majority of heuristic knowledge at the time of this study exists on a project scale with reference to the design phase of the project life cycle.

Table 5 provides a summary of the keywords identified in analyzing sustainable facility heuristics and guidelines. One significant problem apparent from examination of Table 5 is the wide variability in levels of specificity for what variables are considered to be important in defining sustainability. Since rules of thumb are by nature guidance evolved from learning what works in specific situations, variables included for the built environment may legitimately vary based on the phase of problem solving being addressed and the scale and type of facility being analyzed. However, within the sets of comprehensive guidelines addressing multiple life cycle phases, the diversity in variables considered is reflective of the fact that sustainability is still a relatively evolving field.

## **Assessment and Evaluation Tools**

The next class of work in the literature review is closest to being operationally useful for decision-making: assessment and evaluation tools for built environment sustainability. In the context of this analysis, *assessment* refers to a qualitative review of the attributes of a system, while *evaluation* refers to a more quantitative review where specific criteria for success or failure have been pre-defined. Each of the assessment and evaluation tools discussed in this section includes various parameters and objectives of sustainability, along with different sets of built environment variables that the authors consider to be important for sustainability.

### ***Synthesis of Existing Assessment and Evaluation Tools***

This section reviews a total of thirteen assessment- and/or evaluation-related sources. These sources were selected for detailed analysis of the state of the art in building-related sustainability since they represent different scales in facility assessment or evaluation. The scales of applicability range from individual materials [41], to the facility scale [42], to the facility scale plus processes within the facility or larger development [43].

At the individual materials scale, five sources were reviewed. Recently released in its second software-based version, the Building for Economic and Environmental Sustainability (BEES) Index [44] focuses on the scale of individual building materials, and uses six subvariables to describe the environmental vs. economic performance of various materials. Likewise, Lawson's Built Environment Sustainability (BES) Index [45] provides an index of sustainability for construction materials, based on three classes of variables: resource depletion, inherent pollution, and embodied energy. This index is quantitative, based on estimated or calculated values for a number of subvariables describing each of Lawson's parameters. Unfortunately, both of these systems are still in their infancy, and viable values have been calculated for relatively few materials. The other three systems [46] attempt to convey

information on the relative sustainability of building materials and components, using rank order in the first source and “A”, “B”, or “C” ratings in the second two references. These tools are able to provide information for a broader variety of materials due to their approximation of precise values into coarser scales. These tools provide enough (but not too much) information to allow designers and specifiers to select materials based on sustainability criteria.

Other sources have developed whole-facility scale assessment tools being used on a national scale, including:

- Canada’s Building Environmental Performance Assessment Criteria - BEPAC [47]
- Great Britain’s Building Research Establishment Environmental Assessment Method, BREEAM [48]
- The United States’ Leadership in Energy and Environmental Design (LEED) green building rating tool [49]

These tools incorporate aspects of the building life cycle, its surroundings, and the components that comprise it. These tools are largely limited in application to commercial facilities, although versions are under development for residential facilities and other project types as well. The “GBTool” and Green Building Challenge is an international effort to combine the intents of these country-specific tools to allow benchmarking of best sustainable building practices for facilities around the world [50].

Also included in this analysis is a composite analysis of six local green building programs at the city or regional level developed by the U.S. National Association of Home Builders Research Center [51]. This analysis identifies commonalities among variables considered in each of the six programs (which focus on single family detached residential construction), and provides an overview of recommendations and lessons learned for implementation of local green building programs and rating systems.

In contrast to tools that focus on facilities only, the assessment method developed by Graedel & Allenby [52] focuses on manufacturing or industrial facilities, and is one of only two sources uncovered in this review to include the processes housed by the facility in analyzing its “greenness”. Also on this scale, DuBose & Pearce [53] developed an evaluation tool based on the Natural Step approach to sustainability created by Robért and Eriksson [54]. This tool was developed as a first attempt to operationalize the Natural Step to a specific type of technological system, namely built facilities. A third source in this category has developed a set of criteria to apply to whole development projects based on review of project-level assessment tools from several countries, including Environmental Impact Assessment, Cost-benefit analysis, Environmental Value Engineering, and others [55].

### ***Limitations and Opportunities***

As is the case with models and frameworks, the review of assessment and evaluation tools for built environment sustainability from the literature shows that disparities exist in terms of the variables included for consideration. Table 6 provides a summary of the variables unearthed in the analysis of the assessment and evaluation tools.

One notable conclusion to be drawn from this list of built environment and sustainability variables is that the scale and specificity of variables differs remarkably from tool to tool, ranging from global issues like ozone depletion to very component-specific criteria such as product recyclability. The rationale for selecting indicators or measures of each variable is not typically explained in each source. DuBose and Pearce [56] are one exception to this trend in that they specifically explain their rationale for indicator selection, albeit at the expense of actually demonstrating the use of their assessment tool. While the selection of criteria and weightings for most of the tools was based on consensus across populations of tool developers and practitioners (e.g., LEED, BREEAM, Howard's Environmental Profiling System, etc.), differences in factors considered cannot be explained merely by different contexts of the sources in which they were generated. For example, despite the fact that acid rain is a serious problem in the United States as well as Great Britain, this criterion does not appear in any of the U.S. references examined in this analysis (LEED, BEES, NAHBRC, Graedel, DuBose) and in fact only appears in one of the British references. Without any systematic method for identifying significant criteria, a risk exists that potentially serious issues have been omitted altogether.

Other limitations of existing assessment and evaluation tools include scope limitations in terms of variables considered and types of facilities to which the methods apply. One of the tools is also limited in terms of its dependence on databases of information about specific building materials [57]. Unlike the models and frameworks, however, many of these assessment and evaluation tools are actively being used in the real world, and have demonstrated their usefulness in terms of increasing the marketability of those buildings that obtain certification. This real world utility may in fact be one of the reasons these tools are limited in scope to a small number of indicator variables — measurement and tracking of a large number of indicators has thus far been economically or physically infeasible due to the qualitative nature of many sustainability variables. The developers of the LEED tool, in fact, acknowledge these limitations of data and information, and have made explicit provisions for periodic updating of the indicators and thresholds that must be met to achieve a LEED rating [58].

## **Resource Guides**

The last category of literature reviewed was resource guides, defined as compilations of information about specific materials and building technologies to assist building decision-makers in generating alternatives for specific solutions to facility problems. This section reviews a total of eight references in the Resource Guide category of the built environment sustainability literature.

### ***Synthesis of Existing Resource Guides***

The whole population of resource guides is rapidly growing, although many of the guides focus on very limited criteria due to the difficulty of obtaining accurate data. All but one of the resource guides analyzed in this study provide listings of manufacturer contact information and guidance to support materials selection [59]. The remaining resource guide provides more general guidance on materials, technologies, and business strategies for sustainable design and construction [60]. Many of the guides are updated on a periodic basis, but since the green

building materials and services market is so volatile, the guides become quickly outdated. One guide, Iris Communications' Resource for Environmental Design Index (REDI) Guide, is available online [61] and provides free basic listings for products and services that have environmental benefits or promote sustainable construction. While some listed products have links to web sites with more detail, others include only addresses or telephone numbers. Products or services listed at this site must have one or more of the following environmental benefits: save energy; save water; protect buildings from moisture damage; contain post-consumer recycled content; have been sustainably harvested; promote good indoor air quality; be low-toxicity; be ozone-friendly; or make efficient use of limited natural resources. While these requirements are not especially stringent, products and services in the REDI database at least have some documented environmental benefit over traditional products that has been supported with documentation from the manufacturer or provider.

### ***Limitations and Opportunities***

The review of resource guides for built environment sustainability shows that significant disparities exist in terms of the variables included for consideration. Table 7 summarizes the sustainability and built environment variables implicitly or explicitly considered important to define built environment sustainability in the sources reviewed.

One problem apparent from examination of the table is the wide variability in levels of specificity for what variables are considered to be important in defining sustainability. This differing level of specificity among guides is likely due to the difficulty of obtaining building product data, since no common standard exists to specify what data should be monitored by the manufacturer. Nonetheless, even the guides that claim to be about sustainability show an extremely sparse coverage of potential variables, particularly when compared to the broad coverage provided by the other types of literature. Few if any of the guides included in the detailed analysis explicitly discuss the selection of indicators beyond simply stipulating what criteria have been used to include information. These discussions of criteria are not specific enough to be measurable or replicable; however, since the purpose of the guides is to aid designers in generating alternatives for a given need, the onus of detailed evaluation falls to the user once a set of potential alternatives has been generated.

Another limitation of many resource guides, particularly print versions, is the speed with which they become outdated. The Center for Resourceful Building Technology's Guide to Resource Efficient Building Elements (GREBE) is updated and re-released on a regular basis [62]. Others, still in their first edition, will likely be updated in the future [63].

Finally, significant opportunities exist for companies to facilitate the procurement of green or sustainable building materials and technologies. Many of these products, particularly in the United States, are not available from standard distribution networks and must be ordered directly from the manufacturer, posing a challenge to contractors with limited procurement resources or small orders. The time necessary to obtain product information and the time and risk associated with making a comparative judgment about the reliability and effectiveness of a new product prevents many A/E/C professionals from actively investigating these products. No one-stop access to case studies, lessons learned, or other information that could minimize the

risk of using new products is easily available. At present, at least one online company (<http://www.fatearth.com>) is attempting to bridge this gap by connecting materials vendors and suppliers of environmentally friendly products with customers who enter requests at their web site. However, many additional opportunities exist to facilitate the procurement of green products, and significant market intervention may be required before these products become mainstream.

## **Conclusions and Future Research**

A broad body of literature is emerging in the domain of built environment sustainability. Within this literature, the forty-one sources analyzed in this study highlight the large degree of variability among concepts considered to be important to operationalize sustainability for the built environment. Figure 3 shows the spectrum of stakeholders targeted by the sources reviewed in this analysis. The category-specific tables in the previous sections (Tables 2, 3, 5, 6, and 7) illustrate the divergence of variables considered for sources even within the same category.

The understanding of sustainability in the built environment is following a path of evolution as shown in Figure 4 [64]. As shown conceptually in the figure, a number of first generation models, evaluation tools, and assessment methods have evolved from heuristic knowledge to address the need for predictability, control, and optimization in undertaking sustainability improvements, but these models suffer from a lack of alignment with both each other and general sustainability theory (Figure 5 [65]). As detailed in previous sections, these first generation tools are based on divergent implicit theories about the scope and definition of built environment sustainability as reflected in the diversity of variables considered from tool to tool, and the variability in levels of specificity among the variables.

Based on the built environment and sustainability variables found in the literature, one can conclude that existing theories, tools, and techniques are based on differing definitions of sustainability and apply to different parameters of the built environment. No common operationalization of sustainability exists for the domain of the built environment among sources in the published literature, and there is limited agreement about what variables of the built environment are important to consider in predicting or evaluating built facility sustainability.

The significant diversity among references in the literature may be an asset in terms of focusing on problems relevant for a specific location, type of building, or context. However, without some overall organizing framework that defines sustainability for the built environment, there is a significant possibility of omitting vital considerations or unwittingly creating overlaps in concepts that results in “double-counting”, which is particularly perilous for accurate assessment and evaluation of sustainability. For example, acid rain has been listed by one source as an important consideration for evaluating the sustainability of building materials. Acid rain is generally a result of sulfur emissions from fossil fuel power plants, which would also be affected by the embodied energy or energy efficiency of a building material or component. If both these issues are counted for a given material, then the energy-related performance of the material is effectively weighted more strongly than other variables. Without a consistent definition and

operationalization of the concept of sustainability, interdependency of variables can affect the outcomes of evaluation by affording greater weightings to some concepts over others without the analyst even realizing that it is occurring.

This paper provides a point of departure for future research that can begin to address this problem. One purpose of the study was to begin the development of a set of variables that can comprehensively and uniformly define built environment sustainability, based on analysis of a representative spectrum of forty-one literature sources. The set of variables developed in this study can be validated and expanded in future research by more extensive analysis of a larger sample of the published literature using formal text analysis methods such as content analysis [66]. After a comprehensive set of built environment sustainability variables has been identified, these variables can be clustered using established methods such as concept mapping [67] or dendogram analysis [68] to identify gaps and overlaps and develop a parametric representation of sustainability for the built environment.

## Acknowledgments

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## References and Notes

- [1] Graham, P. (1997). *Methods for Assessing the Sustainability of Construction and Development Activity*. Royal Melbourne Institute of Technology, Department of Building and Construction Economics, Melbourne, Australia.; CIB - International Council for Building Research Studies and Documentation. (1998). *Sustainable Development and the Future of Construction: A Comparison of Visions from Various Countries*. CIB Publication 225, W82 - Futures Studies in Construction, Rotterdam, The Netherlands.; NAHB Research Center. (1999). *A Guide to Developing Green Builder Programs*. National Association of Home Builders Research Center, Upper Marlboro, MD, USA.
- [2] For example, a detailed textual analysis of (Kibert, C. (1994). "Establishing Principles and a Model for Sustainable Construction." in Kibert, C.J., ed. *Proceedings of the First International Conference on Sustainable Construction*. Tampa, FL, November 6-9. CIB TG 16.) produced over 400 keywords relating to built environment sustainability using the method of content analysis.
- [3] Spiegel, R. & Meadows, D. (1999). *Green Building Materials: A Guide to Product Selection and Specification*. John Wiley & Sons, New York, NY, USA.
- [4] Barnett, D.L. & Browning, W.D. (1995). *A Primer on Sustainable Building*. Rocky Mountain Institute, Snowmass, CO, USA.

- [5] Langston, C., ed. (1997). *Sustainable Practices: ESD and the Construction Industry*. Envirobook, Sydney, NSW, Australia.
- [6] Woolley, T., Kimmins, S., Harrison, P., and Harrison, R. (1997). *Green Building Handbook*. E & FN Spon, New York, NY, USA.
- [7] Spiegel & Meadows (1999), op cit.
- [8] Yeang, K.P. (1995). *Designing With Nature*. McGraw Hill, New York, NY, USA.; Kibert (1994), op cit.; Lyle, J.T. (1994). *Regenerative Design for Sustainable Development*. Wiley Press, New York, NY, USA.; Vanegas, J.A. and Pearce, A.R. (1997). "Sustainable Design and Construction Strategies for the Built Environment." *Proceedings of the 1997 NESEA Conference*. Boston, MA, USA.
- [9] Hill, R.C, Bergman, J.G., and Bowen, P.A. (1994). "A Framework for the Attainment of Sustainable Construction," in Kibert, C.J., ed. *Proceedings of the First International Conference on Sustainable Construction*. Tampa, FL, November 6-9. CIB TG 16.
- [10] CIB (1998), op cit.
- [11] Kibert (1994), op cit.; Vanegas & Pearce (1997), op cit.
- [12] Lyle (1994), op cit.; Yeang (1995), op cit.
- [13] Hill et al. (1994), op cit.
- [14] CIB (1998), op cit.
- [15] Pearce, A.R. (1999). *Increasing the Sustainability of the Built Environment: A Metric and Process for Prioritizing Improvement Opportunities*. UMI Dissertation Services, Ann Arbor, MI, USA.
- [16] HOK - Hellmuth, Obata & Kassabaum, Inc. (1995). *Sustainable Design Guide*. HOK, Inc., St. Louis, MI, USA, February.
- [17] Ander, G.D. (1994). "A Check List for Sustainable Architectural Design," *Earthword: Sustainable Architecture*, 1(5), 52-53.
- [18] CREST - Center for Renewable Energy and Sustainable Technology et al. (1998). *Green Building Advisor*. Center for Renewable Energy and Sustainable Technology, Washington, DC, USA.
- [19] Dym, C. L. and Levitt, R. E. (1991). *Knowledge-Based Systems in Engineering*. McGraw Hill, New York, NY, USA.
- [20] Mendler, S.F. & Odell, W. (2000). *The HOK Guidebook to Sustainable Design*. John Wiley & Sons, New York, NY, USA.
- [21] Halliday, S.P. (1994). *Environmental Code of Practice for Buildings and their Services*. The Building Services Research and Information Association, Bracknell, Berkshire, UK.
- [22] Austin Green Builder Program. (2000). *Sustainable Building Sourcebook*. <http://www.greenbuilder.com>.
- [23] HOK (1995), op cit.

- [24] PTI - Public Technology, Inc. (1996). *Sustainable Building Technical Manual: Green Building Design, Construction, and Operations*. Public Technology, Inc., Washington, DC, USA.
- [25] *ibid.*
- [26] HOK (1995), *op cit.*
- [27] *ibid.*
- [28] *ibid.*
- [29] Halliday (1994), *op cit.*
- [30] *ibid.*
- [31] HOK (1995), *op cit.*
- [32] PTI (1996), *op cit.*
- [33] Jones-Crabtree, A.J., Pearce, A.R., and Chen, V.T.C. (1998). "Implementing Sustainability Knowledge into the Built Environment: An Assessment of Current Approaches," IERC Conference Proceedings, Banff, BC, Canada, May 9-12.
- [34] U.S. National Park Service (1993). *Guiding Principles of Sustainable Design*. United States Department of the Interior, Denver Service Center, Denver, CO, USA.; North Carolina Recycling Association. (1994). *North Carolina Green Building Charette: Final Report*. North Carolina Recycling Association, Raleigh, NC, USA. April 29-30.
- [35] Vanegas, J.A., DuBose, J.R., and Pearce, A.R. (1995). "Sustainable Technologies for the Building Construction Industry," *Proceedings, Symposium on Design for the Global Environment*, November, Atlanta, GA, USA.; Environmental Building News. (1994). *Checklist for Environmentally Sustainable Design and Construction*. Environmental Building News, Brattleboro, VT, USA.
- [36] HOK (1995), *op cit.*; Halliday (1994), *op cit.*; PTI (1996), *op cit.*; CREST (1998), *op cit.*; Mendler & Odell (2000), *op cit.*; Austin (2000), *op cit.*
- [37] CREST (1998), *op cit.*
- [38] Austin (2000), *op cit.*
- [39] Jones-Crabtree et al. (1998), *op cit.*
- [40] *ibid.*
- [41] Lippiatt, B.C. and Norris, G.A. (1995). "Selecting Environmentally and Economically Balanced Building Materials," *Proceedings, 2nd International Green Building Conference and Exposition - 1995, NIST SP 888*. Fanney, A.H., Whitter, K.M., and Cohn, T.B., eds. National Institute of Standards and Technology, Gaithersburg, MD, USA, 38-46.; Lawson, W.R. (1996). "Appraisal System for Ecologically Sustainable Building." *Proceedings, 2nd National Energy Efficiency in Buildings Conference*, Wollongong, New South Wales, Australia, June.; Anink, D., Boonstra, C., & Mak, J. (1996). *Handbook of Sustainable Building: An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment*. James & James, London, UK.; Howard, N., Shiers, D., & Sinclair, M. (1998). *The Green*

- Guide to Specification: An Environmental Profiling System for Building Materials and Components*. Building Research Establishment, Garston, Watford, UK.; Anderson, J. & Howard, N. (2000). *The Green Guide to Housing Specification*. Building Research Establishment, Construction Research Communications, London, UK.
- [42] Cole, R.J. (1993). *Building Environmental Performance Assessment Criteria (BEPAC) – Office Buildings*. Environmental Research Group, School of Architecture, University of British Columbia, Vancouver, BC, Canada.; Baldwin, R., Yates, A., Howard, N., & Rao, S. (1998). *Building Research Establishment Environmental Assessment Method (BREEAM) 98 for Offices*. Building Research Establishment, Construction Research Communications, London, UK.; Cole, R.J. & Larson, N. (1998). “Green Building Challenge,” *ASHRAE Journal*, May, 1-2.; NAHB Research Center. (1999). *A Guide to Developing Green Builder Programs*. National Association of Home Builders Research Center, Upper Marlboro, MD, USA.; USGBC - U.S. Green Building Council. (2000). *Leadership in Energy & Environmental Design (LEED) Green Building Rating System, v. 2.0*. U.S. Green Building Council, Washington, DC, USA. Available online at <http://www.usgbc.org>.
- [43] Graedel, T.E. and Allenby, B.R. (1995). “Matrix Approaches to Green Facility Assessment”, *Proceedings, Second International Green Buildings Conference, Special Publication 888*, National Institute of Standards and Technology, Gaithersburg, MD, USA, 84-102.; DuBose, J.R. and Pearce, A.R. (1997). “The Natural Step as an Assessment Tool for the Built Environment.” *Proceedings, 1997 CIB Conference on Green Building*, Paris, France, June.; Graham, P. (1997). *Methods for Assessing the Sustainability of Construction and Development Activity*. Royal Melbourne Institute of Technology, Department of Building and Construction Economics, Melbourne, Australia.
- [44] Lippiatt & Norris (1995), op cit.
- [45] Lawson (1996), op cit.
- [46] Anink et al. (1996), op cit.; Howard et al. (1998), op cit.; Anderson & Howard (2000), op cit.
- [47] Cole (1993), op cit.
- [48] Baldwin et al. (1998), op cit.
- [49] USGBC (2000), op cit.
- [50] Cole & Larson (1998), op cit.
- [51] NAHB Research Center (1999), op cit.
- [52] Graedel & Allenby (1995), op cit.
- [53] DuBose & Pearce (1997), op cit.
- [54] Robért, K.H., Holmberg, J., and Eriksson, K.E. (1994). “Socio-ecological Principles for a Sustainable Society: Scientific Background and Swedish Experience.” The Natural Step Foundation, San Francisco, CA, USA.

- [55] Graham (1997), op cit.
- [56] DuBose & Pearce (1997), op cit.
- [57] Lippiatt & Norris (1995), op cit.
- [58] USGBC can be found online at <http://www.usgbc.org>. The latest release of the LEED Green Building Rating System is also posted on this site and can be downloaded as a PDF file.
- [59] Bennett (1990). *The Green Pages*. Bennett Information Group, Random House, New York, NY, USA.; St. John, A. (1992). *The Sourcebook for Sustainable Design: A Guide to Environmentally Responsible Building Materials and Processes*. Boston Society of Architects, Boston, MA, USA.; Dadd-Redalia, D.L. (1994). *Sustaining the Earth: Choosing Consumer Products that are Safe for You, Your Family, and the Earth*. Hearst Publishing, New York, NY, USA.; Loken, S., Miner, R., and Mumma, T. (1994). *A Reference Guide to Resource Efficient Building Elements, 4th ed.* Center for Resourceful Building Technology, Missoula, MT, USA.; Hermannsson, J. (1997). *Green Building Resource Guide*. Taunton Press, Newtown, CT, USA.; Holmes, D., Strain, L., Wilson, A., & Leibowitz, S. (1999). *GreenSpec: The Environmental Building News Product Directory and Guideline Specifications*. E-Build, Inc., Brattleboro, VT, USA.
- [60] O'Brien, M. and Palermi, D. (1993). *Guide to Resource Efficient Building*. Guide, Building With Value '93 Resource-Efficient Construction Conference and Trade Show. The Sustainable Building Collaborative, Portland, OR, USA.
- [61] Iris Communications. (1994). *The REDI (Resources for Environmental Design Index) Guide*. Iris Communications, Eugene, OR, USA. Also available online at <http://data.oikos.com/products/>.
- [62] Loken et al. (1994), op cit.
- [63] Hermannsson (1997), op cit.; Holmes et al. (1999), op cit.
- [64] Pearce (1999), op cit.
- [65] *ibid.*
- [66] Carney, T.F. (1972). *Content Analysis*. University of Manitoba Press, Winnipeg, Canada.; U.S. General Accounting Office. (1996). *Content Analysis: A methodology for structuring and analyzing written material*. Program Evaluation and Methodology Division, United States General Accounting Office, Washington, DC, USA.; Krippendorff, K. (1980). *Content Analysis – An Introduction to its Methodology*. Sage Publications, Beverly Hills, CA, USA.; Carley, K. (1993). "Coding choices for textual analysis: A comparison of content analysis and map analysis." *Sociological Methodology*, 23, 75-126.
- [67] Trochim, W. (1989). "An introduction to concept mapping for planning and evaluation." *Evaluation and Program Planning*, 12(1), 1-16. Available online at <http://www.conceptsystems.com/papers/epp1/epp1.htm>; Keith, D. (1989). "Refining concept maps: Methodological issues and an example." *Evaluation and Program Planning*. 12(1), 75-80.; Dumont, J. (1989). "Validity of multidimensional scaling in the

context of structured conceptualization.” *Evaluation and Program Planning*. 12(1), 81-86.; Cooksy, L. (1989). “In the eye of the beholder: Relational and hierarchical structures in conceptualization.” *Evaluation and Program Planning*. 12(1), 59-66.; Rosenberg, S. and Kim, M.P. (1975). “The method of sorting as a data-gathering procedure in multivariate research.” *Multivariate Behavioral Research*, 10, 489-502.; Everitt, B. (1980). *Cluster Analysis*, 2<sup>nd</sup> ed. Halsted Press, New York, NY.

- [68] Krippendorff (1980), op cit.; Anderberg, M.R. (1973). *Cluster analysis for applications*. Academic Press, New York, NY.

## Tables

**Table 1: Sources Included in Parametric Analysis**

	<b>AUTHOR(S)</b>	<b>YEAR</b>	<b>TITLE</b>	<b>SOURCE</b>
<b>GENERAL REFERENCES</b>	Barnett, D.L. & Browning, W.D.	1995	A Primer on Sustainable Building	Rocky Mountain Institute, Snowmass, CO, USA.
	Langston, C., ed.	1997	Sustainable Practices: ESD and the Construction Industry	Envirobook, Sydney, NSW, Australia.
	Woolley, T., Kimmins, S., Harrison, P., & Harrison, R.	1997	Green Building Handbook	E & FN Spon, London, UK.
	Spiegel, R. & Meadows, D.	1999	Green Building Materials: A Guide to Product Selection and Specification	John Wiley & Sons, New York, NY, USA.
<b>MODELS &amp; FRAMEWORKS</b>	Yeang, K.P.	1993	Designing With Nature	McGraw Hill, New York, NY, USA.
	Kibert, C.J.	1994	Establishing Principles and a Model for Sustainable Construction	in Kibert, C.J., ed. Proceedings of the First International Conference on Sustainable Construction. Tampa, FL, November 6-9. CIB TG 16.
	Lyle, J.T.	1994	Regenerative Design for Sustainable Development	John Wiley & Sons, New York, NY, USA.
	Hill, R.C, Bergman, J.G., and Bowen, P.A.	1994	A Framework for the Attainment of Sustainable Construction	in Kibert, C.J., ed. Proceedings of the First International Conference on Sustainable Construction. Tampa, FL, November 6-9. CIB TG 16.
	Vanegas, J.A. & Pearce, A.R.	1997	Sustainable Design and Construction Strategies for the Built Environment	Proceedings of the 1997 NESEA Conference. Boston, MA.
	CIB - International Council for Building Research Studies and Documentation	1998	Sustainable Development and the Future of Construction: A Comparison of Visions from Various Countries	CIB Publication 225, W82 - Futures Studies in Construction, Rotterdam, The Netherlands.
<b>HEURISTICS &amp; GUIDELINES</b>	United States National Park Service	1993	Guiding Principles of Sustainable Design	United States Department of the Interior, Denver Service Center, Denver, CO, USA.
	North Carolina Recycling Association	1994	North Carolina Green Building Charette: Final Report	North Carolina Recycling Association, Raleigh, NC, USA. April 29-30.
	Environmental Building News	1994	Checklist for Environmentally Sustainable Design and Construction	Environmental Building News, Brattleboro, VT, USA.
	Hellmuth, Obata, & Kassabaum	1994	Sustainable Design Guide	HOK, Inc., St. Louis, MI, USA.
	Halliday, S.P.	1994	Environmental Code of Practice for Buildings and their Services	The Building Services Research and Information Association, Bracknell, Berkshire, UK.
	Vanegas, J.A., DuBose, J.R., and Pearce, A.R.	1995	Sustainable Technologies for the Building Construction Industry	Proceedings, Symposium on Design for the Global Environment, November, Atlanta, GA, USA.

	<b>AUTHOR(S)</b>	<b>YEAR</b>	<b>TITLE</b>	<b>SOURCE</b>
	Public Technologies, Inc.	1996	Sustainable Building Technical Manual: Green Building Design, Construction, and Operations	Public Technology, Inc., Washington, DC, USA.
	Center for Renewable Energy and Sustainable Technology et al.	1998	Green Building Advisor	Center for Renewable Energy and Sustainable Technology, Washington, DC, USA.
	Mendler, S.F. & Odell, W.	2000	The HOK Guidebook to Sustainable Design	John Wiley & Sons, New York, NY, USA.
	Austin Green Builder Program	2000	Sustainable Building Sourcebook	<a href="http://www.greenbuilder.com">http://www.greenbuilder.com</a>
<b>ASSESSMENT &amp; EVALUATION TOOLS</b>	Cole, R.J.	1993	Building Environmental Performance Assessment Criteria (BEPAC) – Office Buildings	Environmental Research Group, School of Architecture, University of British Columbia, Vancouver, BC, Canada.
	Graedel, T.E. & Allenby, B.R.	1995	Matrix Approaches to Green Facility Assessment	Proceedings, 2nd International Green Buildings Conference, Special Publication 888, National Institute of Standards and Technology, Gaithersburg, MD, USA, 84-102.
	Lippiatt, B.C. & Norris, G.A.	1995	Selecting Environmentally and Economically Balanced Building Materials	Proceedings, 2nd International Green Building Conference and Exposition - 1995, NIST SP 888. Fanney, A.H., Whitter, K.M., and Cohn, T.B., eds. National Institute of Standards and Technology, Gaithersburg, MD, USA, 38-46.
	Lawson, W.R.	1996	Appraisal System for Ecologically Sustainable Building	Proceedings, 2nd National Energy Efficiency in Buildings Conference, Wollongong, New South Wales, Australia, June.
	Anink, D., Boonstra, C., & Mak, J.	1996	Handbook of Sustainable Building: An Environmental Preference Method for Selection of Materials for Use in Construction and Refurbishment	James & James, London, UK.
	DuBose, J.R. & Pearce, A.R.	1997	The Natural Step as an Assessment Tool for the Built Environment	Proceedings, 1997 CIB Conference on Green Building, Paris, France, June.
	Graham, P.	1997	Methods for Assessing the Sustainability of Construction and Development Activity	Royal Melbourne Institute of Technology, Department of Building and Construction Economics, Melbourne, Australia.
	Baldwin, R., Yates, A., Howard, N., & Rao, S.	1998	Building Research Establishment Environmental Assessment Method (BREEAM) 98 for Offices	Building Research Establishment, Construction Research Communications, London, UK.
	Howard, N., Shiers, D., & Sinclair, M.	1998	The Green Guide to Specification: An Environmental Profiling System for Building Materials and Components	Building Research Establishment, Garston, Watford, UK.

	<b>AUTHOR(S)</b>	<b>YEAR</b>	<b>TITLE</b>	<b>SOURCE</b>
	Cole, R.J. & Larson, N.	1998	Green Building Challenge	ASHRAE Journal, May, 1-2.
	NAHB Research Center	1999	A Guide to Developing Green Builder Programs	National Association of Home Builders Research Center, Upper Marlboro, MD, USA.
	Anderson, J. & Howard, N.	2000	The Green Guide to Housing Specification	Building Research Establishment, Construction Research Communications, London, UK.
	U.S. Green Building Council	2000	Leadership in Energy & Environmental Design (LEED) Green Building Rating System, v. 2.0	U.S. Green Building Council, Washington, DC, USA.
<b>RESOURCE GUIDES</b>	Bennett Group	1990	The Green Pages	Bennett Information Group, Random House, New York, NY, USA.
	St. John, A.	1992	The Sourcebook for Sustainable Design: A Guide to Environmentally Responsible Building Materials and Processes	Boston Society of Architects, Boston, MA, USA.
	O'Brien, M. and Palermini, D.	1993	Guide to Resource Efficient Building	Building With Value '93: Resource-Efficient Construction Conference and Trade Show. The Sustainable Building Collaborative, Portland, OR, USA.
	Dadd-Redalia, D.L.	1994	Sustaining the Earth	Hearst Publishing, New York, NY, USA.
	Iris Communications	1994	The REDI (Resources for Environmental Design Index) Guide	Iris Communications, Eugene, OR, USA. Also available online at <a href="http://data.oikos.com/products/">http://data.oikos.com/products/</a> .
	Loken, S., Miner, R., & Mumma, T.	1994	A Reference Guide to Resource Efficient Building Elements, 4th ed.	Center for Resourceful Building Technology, Missoula, MT, USA.
	Hermannsson, J.	1997	Green Building Resource Guide	Taunton Press, Newtown, CT, USA.
	Holmes, D., Strain, L., Wilson, A., & Leibowitz, S.	1999	GreenSpec: The Environmental Building News Product Directory and Guideline Specifications	E-Build, Inc., Brattleboro, VT, USA.

**Table 2: General References on Built Environment Sustainability**

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<p><b>Barnett &amp; Browning (1995)</b> "Primer on Sustainable Building"</p>	<ul style="list-style-type: none"> <li>• Architects and their clients</li> <li>• Home builders</li> <li>• Developers</li> <li>• Contractors</li> <li>• Landscape architects</li> <li>• Owner-builders</li> </ul> <p>Overall, a lay audience</p>	<ul style="list-style-type: none"> <li>• Appropriate land use</li> <li>• Resource efficiency</li> <li>• Human health</li> <li>• Local economy/community</li> <li>• Conservation of:                             <ul style="list-style-type: none"> <li>• <i>Plants</i></li> <li>• <i>Animals</i></li> <li>• <i>Endangered species</i></li> <li>• <i>Habitats</i></li> </ul> </li> <li>• Protection of:                             <ul style="list-style-type: none"> <li>• <i>Agricultural resources</i></li> <li>• <i>Cultural resources</i></li> <li>• <i>Archaeological resources</i></li> </ul> </li> <li>• Quality of life</li> <li>• Economical construction/operation</li> </ul>	<ul style="list-style-type: none"> <li>• Site selection</li> <li>• Site development</li> <li>• Transportation</li> <li>• Building placement</li> <li>• Land design</li> <li>• Building configuration</li> <li>• Building shell</li> <li>• Energy use inside</li> <li>• Saving water</li> <li>• Building ecology</li> <li>• Operations</li> <li>• Specification and construction</li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<p><b>Langston (1997)</b> "Sustainable Practices"</p>	<ul style="list-style-type: none"> <li>• Construction Industry</li> <li>• Academics and students</li> </ul>	<ul style="list-style-type: none"> <li>• Environmental protection</li> <li>• Environmental quality: <ul style="list-style-type: none"> <li>• <i>Planet in crisis</i></li> <li>• <i>Sustainable development</i></li> <li>• <i>Environmental accounting</i></li> </ul> </li> <li>• Development Controls: <ul style="list-style-type: none"> <li>• <i>Environmental Impact Assessment</i></li> <li>• <i>Environmental Law</i></li> <li>• <i>Environmental policies/strategies</i></li> </ul> </li> <li>• Design considerations: <ul style="list-style-type: none"> <li>• <i>Environmental impact</i></li> <li>• <i>Low energy design</i></li> <li>• <i>Alternative technologies</i></li> </ul> </li> <li>• Energy conservation: <ul style="list-style-type: none"> <li>• <i>Embodied energy &amp; recycling</i></li> <li>• <i>Energy quality</i></li> <li>• <i>Energy regulation &amp; policy</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Economic rationalism</li> <li>• Analytical tools: <ul style="list-style-type: none"> <li>• <i>Environmental economics</i></li> <li>• <i>Cost-benefit analysis</i></li> <li>• <i>Social costs &amp; benefits</i></li> </ul> </li> <li>• Project feasibility: <ul style="list-style-type: none"> <li>• <i>Project selection criteria</i></li> <li>• <i>Intergenerational equity</i></li> <li>• <i>Sustainability constraint</i></li> </ul> </li> <li>• Life cycle cost: <ul style="list-style-type: none"> <li>• <i>Planning and analysis</i></li> <li>• <i>Discount rate</i></li> <li>• <i>Occupancy costs</i></li> </ul> </li> <li>• Asset management: <ul style="list-style-type: none"> <li>• <i>Energy auditing</i></li> <li>• <i>Post-occupancy evaluation</i></li> <li>• <i>Facility management</i></li> </ul> </li> <li>• Strategic planning</li> <li>• Project design &amp; management</li> </ul>
<p><b>Woolley et al. (1997)</b> "Green Building Handbook"</p>	<ul style="list-style-type: none"> <li>• Specifiers</li> <li>• Clients</li> <li>• Communities</li> <li>• Voluntary groups</li> </ul>	<ul style="list-style-type: none"> <li>• Production: <ul style="list-style-type: none"> <li>• <i>Energy use</i></li> <li>• <i>Resource depletion (biological)</i></li> <li>• <i>Resource depletion (non-biological)</i></li> <li>• <i>Global warming</i></li> <li>• <i>Ozone depletion</i></li> <li>• <i>Toxics</i></li> <li>• <i>Acid rain</i></li> <li>• <i>Photochemical oxidants</i></li> </ul> </li> <li>• Use: <ul style="list-style-type: none"> <li>• <i>Energy use</i></li> <li>• <i>Durability/maintenance</i></li> <li>• <i>Recycling/reuse/disposal</i></li> <li>• <i>Health hazards</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Energy</li> <li>• Insulation materials</li> <li>• Masonry</li> <li>• Timber</li> <li>• Composite boards</li> <li>• Timber preservatives</li> <li>• Window frames</li> <li>• Paints and stains for joinery</li> <li>• Roofing materials</li> <li>• Rainwater goods</li> <li>• Toilets and sewage disposal</li> <li>• Carpets and floor coverings</li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
Spiegel & Meadows (1999) "Green Building Materials"	<ul style="list-style-type: none"> <li>Architects</li> <li>Specifiers</li> </ul>	<ul style="list-style-type: none"> <li>Resource management: <ul style="list-style-type: none"> <li><i>Pollution</i></li> <li><i>Depletion</i></li> <li><i>Destruction</i></li> </ul> </li> <li>Toxicity/Indoor Environmental Quality: <ul style="list-style-type: none"> <li><i>Indoor air quality</i></li> <li><i>Bioaccumulation</i></li> </ul> </li> <li>Performance: <ul style="list-style-type: none"> <li><i>Installation methods</i></li> <li><i>Maintenance materials/processes</i></li> <li><i>Durability</i></li> <li><i>Energy efficiency</i></li> <li><i>Recyclability</i></li> <li><i>Reusability</i></li> <li><i>Impact on global commons</i></li> <li><i>Worker productivity</i></li> <li><i>Customer satisfaction</i></li> </ul> </li> </ul>	CSI Divisions 2-16: <ul style="list-style-type: none"> <li>Site construction</li> <li>Concrete</li> <li>Masonry</li> <li>Metals</li> <li>Woods and plastics</li> <li>Thermal and moisture protection</li> <li>Doors and windows</li> <li>Finishes</li> <li>Specialties</li> <li>Equipment</li> <li>Furnishings</li> <li>Special construction</li> <li>Conveying systems</li> <li>Mechanical</li> <li>Electrical</li> </ul>

**Table 3: Models and Frameworks of Built Environment Sustainability**

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
Yeang (1993)	<ul style="list-style-type: none"> <li>Designers/Architects</li> </ul>	<ul style="list-style-type: none"> <li>Ecosystem Impacts: <ul style="list-style-type: none"> <li><i>Spatial heterogeneity</i></li> <li><i>Spatial displacement</i></li> <li><i>Assimilative ability</i></li> </ul> </li> <li>Resource Use: <ul style="list-style-type: none"> <li><i>Energy</i></li> <li><i>Materials</i></li> <li><i>User Requirements</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Built System</li> <li>Environmental Context of System</li> <li>System/Environment Interactions: <ul style="list-style-type: none"> <li><i>External interdependencies</i></li> <li><i>Internal interdependencies</i></li> <li><i>System inputs</i></li> <li><i>System outputs</i></li> </ul> </li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>Hill et al. (1994)</b>	<ul style="list-style-type: none"> <li>• Policy makers</li> <li>• Construction Industry</li> </ul>	<ul style="list-style-type: none"> <li>• Economic and Social: <ul style="list-style-type: none"> <li>• <i>Quality of human life</i></li> <li>• <i>Social disruption</i></li> <li>• <i>Equitable costs/benefits</i></li> </ul> </li> <li>• Environmental: <ul style="list-style-type: none"> <li>• <i>Biological systems</i></li> <li>• <i>Biodiversity</i></li> <li>• <i>Resources</i></li> <li>• <i>Damage to sensitive areas</i></li> <li>• <i>Construction pollution</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Construction Impacts</li> <li>• Organizational Structure</li> <li>• Operational/Audit Procedures</li> <li>• Record Keeping</li> <li>• Environmental Awareness</li> <li>• Standards/Penalties/Bonuses</li> <li>• Environmental Management</li> </ul>
<b>Kibert (1994)</b>	<p>Construction Industry:</p> <ul style="list-style-type: none"> <li>• Developers</li> <li>• Planners</li> <li>• Architects</li> <li>• Engineers</li> <li>• Builders/Constructors</li> <li>• Operators</li> </ul>	<ul style="list-style-type: none"> <li>• Resources: <ul style="list-style-type: none"> <li>• <i>Conservation</i></li> <li>• <i>Degradation</i></li> <li>• <i>Reuse</i></li> <li>• <i>Renewability</i></li> <li>• <i>Recyclability</i></li> </ul> </li> <li>• Environment: <ul style="list-style-type: none"> <li>• <i>Impact</i></li> <li>• <i>Degradation</i></li> <li>• <i>Toxicity</i></li> <li>• <i>Quality</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Energy consumption</li> <li>• Water use</li> <li>• Land use</li> <li>• Materials selection</li> <li>• Indoor environmental quality</li> <li>• Exterior environmental quality</li> <li>• Building design</li> <li>• Community design</li> <li>• Construction operations</li> <li>• Life cycle operation</li> <li>• Deconstruction</li> <li>• Embodied energy content</li> <li>• Greenhouse warming gases</li> <li>• Toxics generated/content</li> </ul>
<b>Lyle (1994)</b>	<ul style="list-style-type: none"> <li>• Landscape architects</li> <li>• Civil engineers</li> <li>• Architects</li> <li>• Land development planners</li> <li>• Students</li> <li>• Educators</li> </ul>	<ul style="list-style-type: none"> <li>• Resource use: <ul style="list-style-type: none"> <li>• <i>Renewable</i></li> <li>• <i>Nonrenewable</i></li> </ul> </li> <li>• Waste: <ul style="list-style-type: none"> <li>• <i>Generation</i></li> <li>• <i>Composition</i></li> <li>• <i>Assimilation</i></li> </ul> </li> <li>• Systems integration: <ul style="list-style-type: none"> <li>• <i>Human social systems</i></li> <li>• <i>Natural ecological systems</i></li> <li>• <i>Human technology systems</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Energy</li> <li>• Water</li> <li>• Waste</li> <li>• Materials: <ul style="list-style-type: none"> <li>• <i>Embedded energy</i></li> <li>• <i>Renewability</i></li> <li>• <i>Permanence/Reusability</i></li> </ul> </li> <li>• Indoor Air Pollution</li> <li>• Density</li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>Vanegas &amp; Pearce (1997)</b>	Construction Industry: <ul style="list-style-type: none"> <li>• Developers</li> <li>• Planners</li> <li>• Architects</li> <li>• Engineers</li> <li>• Builders/Constructors</li> <li>• Operators</li> </ul> Insurance Industry	<ul style="list-style-type: none"> <li>• Natural resources:               <ul style="list-style-type: none"> <li>• <i>Consumption</i></li> <li>• <i>Depletion</i></li> <li>• <i>Degradation</i></li> </ul> </li> <li>• Waste:               <ul style="list-style-type: none"> <li>• <i>Generation</i></li> <li>• <i>Accumulation</i></li> </ul> </li> <li>• Environment:               <ul style="list-style-type: none"> <li>• <i>Impact</i></li> <li>• <i>Degradation</i></li> </ul> </li> <li>• Humans:               <ul style="list-style-type: none"> <li>• <i>Needs</i></li> <li>• <i>Aspirations</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Built environment health</li> <li>• Integration with ecological systems</li> <li>• Economic valuation</li> <li>• Infrastructure requirements</li> <li>• Waste recovery</li> <li>• Construction process technology</li> <li>• Building technology</li> <li>• Stakeholder integration</li> </ul>
<b>CIB (1998)</b>	<ul style="list-style-type: none"> <li>• Researchers</li> <li>• Policy makers</li> </ul>	<ul style="list-style-type: none"> <li>• Traditional factors:               <ul style="list-style-type: none"> <li>• <i>Time</i></li> <li>• <i>Cost</i></li> <li>• <i>Quality</i></li> </ul> </li> <li>• New paradigm:               <ul style="list-style-type: none"> <li>• <i>Resources</i></li> <li>• <i>Emissions</i></li> <li>• <i>Biodiversity</i></li> </ul> </li> <li>• Global context:               <ul style="list-style-type: none"> <li>• <i>Social equity/cultural issues</i></li> <li>• <i>Economic constraints</i></li> <li>• <i>Environmental quality</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Quality and property value</li> <li>• Future user needs/adaptability</li> <li>• Prolonged service life</li> <li>• Use of local resources</li> <li>• Building process</li> <li>• Efficient land use</li> <li>• Water saving</li> <li>• Use of by-products</li> <li>• Distribution of relevant info.</li> <li>• Immaterial services</li> <li>• Urban development and mobility</li> <li>• Human resources</li> <li>• Local economy</li> </ul>

**Table 4:** Class Categorization Factors for Sustainability Guidelines [33]

	<b>Domain Specificity</b>	<b>Evaluability</b>	<b>Operability by Non-experts</b>
<b>Principle</b>	No	No	No
<b>Heuristic</b>	Yes	No/Yes	No
<b>Specification</b>	Yes	Yes	Yes

**Table 5: Heuristics and Guidelines for Creating a Sustainable Built Environment**

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>Design Guidelines</b>			
<b>National Park Service (1993)</b> "Guiding Principles of Sustainable Design"	<ul style="list-style-type: none"> <li>• Owners and operators of U.S. National Park Facilities</li> <li>• Engineers</li> <li>• Landscape architects</li> <li>• Designers/Architects</li> </ul>	<ul style="list-style-type: none"> <li>• Natural resources</li> <li>• Cultural resources</li> <li>• Energy management</li> <li>• Water supply</li> <li>• Waste prevention</li> </ul>	<ul style="list-style-type: none"> <li>• Site design</li> <li>• Building design</li> <li>• Facility maintenance/operations</li> <li>• Energy conservation</li> <li>• Energy efficiency</li> </ul>
<b>NC Recycling (1994)</b> "North Carolina Green Building Charette"	<ul style="list-style-type: none"> <li>• Designers/Architects</li> <li>• Owners</li> </ul>	<ul style="list-style-type: none"> <li>• Energy</li> <li>• Resource consumption</li> <li>• Healthy environments</li> <li>• Waste management/recycling</li> <li>• Operations/maintenance/procurement</li> </ul>	<ul style="list-style-type: none"> <li>• Site</li> <li>• Building codes and inspection</li> <li>• Energy systems</li> <li>• Mechanical systems</li> <li>• Materials/finishes/fixtures/furniture</li> </ul>
<b>Construction Guidelines</b>			
<b>Environmental Building News (1994)</b> "Checklist for Environmentally Sustainable Design and Construction"	<ul style="list-style-type: none"> <li>• Designers/Architects/Engineers</li> <li>• Constructors</li> </ul>	<ul style="list-style-type: none"> <li>• Resource use: <ul style="list-style-type: none"> <li>• <i>Materials</i></li> <li>• <i>Energy</i></li> <li>• <i>Efficiency</i></li> </ul> </li> <li>• Environmental Impacts: <ul style="list-style-type: none"> <li>• <i>Toxics</i></li> <li>• <i>Sensitive ecosystems</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Design</li> <li>• Siting</li> <li>• Materials</li> <li>• Equipment</li> <li>• Job Site</li> </ul>
<b>Vanegas et al. (1995)</b> "Sustainable Technologies for the Building Construction Industry"	<ul style="list-style-type: none"> <li>• Constructors</li> <li>• Planners</li> <li>• Owners</li> <li>• Designers/Architects/Engineers</li> </ul>	<ul style="list-style-type: none"> <li>• Resource consumption</li> <li>• Environmental impact</li> <li>• Human Satisfaction</li> </ul>	<ul style="list-style-type: none"> <li>• Time</li> <li>• Cost</li> <li>• Quality</li> </ul>
<b>Comprehensive Guidelines</b>			

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>HOK (1994)</b> "Sustainable Design Guide"	<ul style="list-style-type: none"> <li>• Architects</li> <li>• Interior designers</li> <li>• Project managers</li> <li>• Building owners</li> <li>• Construction managers</li> <li>• Consultants</li> </ul>	<ul style="list-style-type: none"> <li>• Site development impacts</li> <li>• Pollution prevention</li> <li>• Building durability</li> <li>• Efficiency:               <ul style="list-style-type: none"> <li>• <i>Energy</i></li> <li>• <i>Resources</i></li> </ul> </li> <li>• Materials:               <ul style="list-style-type: none"> <li>• <i>Ecologically sound</i></li> <li>• <i>Healthy</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Site</li> <li>• Energy</li> <li>• Materials</li> <li>• Indoor air quality</li> <li>• Water conservation</li> <li>• Recycling and waste management</li> <li>• Stakeholder partnerships</li> <li>• Public dialog and education</li> </ul>
<b>Halliday (1994)</b> "Environmental Code of Practice for Buildings and their Services"	<ul style="list-style-type: none"> <li>• Procurers</li> <li>• Design team</li> <li>• Professional institutions</li> <li>• Contractors</li> <li>• Manufacturers and suppliers</li> <li>• Owners</li> <li>• Occupiers</li> </ul>	Environmental performance: <ul style="list-style-type: none"> <li>• Human health and safety</li> <li>• Environmental damage</li> <li>• Energy consumption</li> <li>• Materials from threatened species or environments</li> <li>• Human satisfaction</li> <li>• Waste generation</li> <li>• Renewable resources</li> </ul>	Facility Life Cycle: <ul style="list-style-type: none"> <li>• Pre-design</li> <li>• Design</li> <li>• Preparing to Build</li> <li>• Construction</li> <li>• Occupation</li> <li>• Refurbishment</li> <li>• Demolition</li> </ul>
<b>PTI (1996)</b> "Sustainable Building Technical Manual"	<ul style="list-style-type: none"> <li>• Landscape architects</li> <li>• Planners</li> <li>• Architects/Engineers</li> <li>• Interior designers</li> <li>• Contractors</li> <li>• Property managers/mtce staff</li> <li>• Building owners and developers</li> <li>• Product manufacturers</li> <li>• Utility companies</li> <li>• Building tenants</li> <li>• Code/government officials</li> </ul>	<ul style="list-style-type: none"> <li>• Energy efficiency</li> <li>• Water efficiency</li> <li>• Waste reduction</li> <li>• Construction costs</li> <li>• Building maintenance &amp; management savings</li> <li>• Insurance &amp; liability</li> <li>• User health/productivity</li> <li>• Building value</li> </ul>	<ul style="list-style-type: none"> <li>• Pre-Design</li> <li>• Site Issues</li> <li>• Building Design:               <ul style="list-style-type: none"> <li>• Passive solar design</li> <li>• Indoor Environmental Quality</li> <li>• Materials and specifications</li> </ul> </li> <li>• Local Government</li> <li>• Construction</li> <li>• Operations and Maintenance</li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>CREST (1998)</b> "Green Building Advisor"	<ul style="list-style-type: none"> <li>• Architects</li> <li>• Designers</li> <li>• Builders</li> <li>• Planners</li> <li>• Students</li> <li>• Educators</li> <li>• Private companies</li> <li>• Government agencies</li> <li>• Homeowners</li> </ul>	<ul style="list-style-type: none"> <li>• Site &amp; ecosystems:               <ul style="list-style-type: none"> <li>• <i>Site selection</i></li> <li>• <i>Land development</i></li> <li>• <i>Stormwater/Landscaping</i></li> <li>• <i>Regional integration</i></li> </ul> </li> <li>• Resources &amp; materials:               <ul style="list-style-type: none"> <li>• <i>Resource efficiency</i></li> <li>• <i>C&amp;D waste management</i></li> <li>• <i>Future waste minimization</i></li> <li>• <i>Materials by CSI Division</i></li> </ul> </li> <li>• Indoor environment:               <ul style="list-style-type: none"> <li>• <i>Biological pollution</i></li> <li>• <i>Chemical pollution</i></li> <li>• <i>Hazardous materials</i></li> <li>• <i>Ventilation/Monitoring</i></li> <li>• <i>Visual/acoustic quality</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Energy use:               <ul style="list-style-type: none"> <li>• <i>Building envelope</i></li> <li>• <i>Heating, cooling, &amp; ventilation</i></li> <li>• <i>Lighting</i></li> <li>• <i>Appliances &amp; equipment</i></li> <li>• <i>Water heating</i></li> <li>• <i>Energy sources</i></li> </ul> </li> <li>• Water use:               <ul style="list-style-type: none"> <li>• <i>Landscaping</i></li> <li>• <i>Plumbing &amp; fixtures</i></li> <li>• <i>Appliances</i></li> <li>• <i>General</i></li> </ul> </li> </ul>
<b>Mendler &amp; Odell (2000)</b> "Guidebook to Sustainable Design"	<ul style="list-style-type: none"> <li>• Architects</li> <li>• Engineers</li> <li>• Planners</li> <li>• Interior designers</li> <li>• Landscape architects</li> </ul>	<ul style="list-style-type: none"> <li>• Ecosystem protection/ restoration of natural systems</li> <li>• Livable communities</li> <li>• Resource efficiency:               <ul style="list-style-type: none"> <li>• <i>Energy</i></li> <li>• <i>Water</i></li> <li>• <i>Land</i></li> <li>• <i>Materials</i></li> </ul> </li> <li>• Healthy indoor environments</li> </ul>	<ul style="list-style-type: none"> <li>• General issues</li> <li>• Planning and site work</li> <li>• Energy</li> <li>• Water</li> <li>• Indoor environmental quality</li> <li>• Material resources</li> <li>• Fossil fuel reduction/ displacement</li> <li>• Waste/pollution elimination:               <ul style="list-style-type: none"> <li>• <i>Material production</i></li> <li>• <i>Construction</i></li> <li>• <i>Use</i></li> <li>• <i>Disposal</i></li> </ul> </li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<p><b>Austin Green Builder Program (2000)</b> "Sustainable Building Sourcebook"</p>	<ul style="list-style-type: none"> <li>• Homeowners</li> <li>• Builders</li> <li>• Designers</li> <li>• Developers</li> <li>• Contractors</li> </ul> <p>Focus is primarily residential; Texas-specific</p>	<ul style="list-style-type: none"> <li>• Water: <ul style="list-style-type: none"> <li>• <i>Indoor water conservation</i></li> <li>• <i>Composting toilets</i></li> <li>• <i>Pervious materials</i></li> <li>• <i>Xeriscape</i></li> <li>• <i>Greywater irrigation</i></li> <li>• <i>Harvested rainwater</i></li> <li>• <i>Water budget</i></li> </ul> </li> <li>• Energy: <ul style="list-style-type: none"> <li>• <i>Energy Star ratings</i></li> <li>• <i>Passive solar design</i></li> <li>• <i>Landscaping for energy conservation</i></li> <li>• <i>Radiant barrier and ridge-and-soffit venting</i></li> <li>• <i>Earth-sheltered design</i></li> <li>• <i>Solar hot water, heating, and cooling systems</i></li> <li>• <i>Photovoltaic systems</i></li> <li>• <i>Gas water heating systems</i></li> <li>• <i>Ductwork &amp; Fans</i></li> <li>• <i>Energy recovery ventilator</i></li> <li>• <i>Programmable thermostats</i></li> <li>• <i>Energy efficient appliances</i></li> <li>• <i>Lighting</i></li> <li>• <i>Electromagnetic fields</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Building Materials: <ul style="list-style-type: none"> <li>• <i>Dimensional lumber</i></li> <li>• <i>Wood treatment</i></li> <li>• <i>Engineered structural materials</i></li> <li>• <i>Engineered sheet materials</i></li> <li>• <i>Engineered siding and trim</i></li> <li>• <i>Flyash concrete</i></li> <li>• <i>Non-toxic termite control</i></li> <li>• <i>Earth materials</i></li> <li>• <i>Floor coverings</i></li> <li>• <i>Wood flooring</i></li> <li>• <i>Roofing</i></li> <li>• <i>Structural wall panels</i></li> <li>• <i>Insulation</i></li> <li>• <i>Windows and doors</i></li> <li>• <i>Cabinets</i></li> <li>• <i>Paints, finishes, and adhesives</i></li> <li>• <i>Straw bale construction</i></li> </ul> </li> <li>• Solid Waste: <ul style="list-style-type: none"> <li>• <i>Home recycling</i></li> <li>• <i>Compost systems</i></li> <li>• <i>Construction waste recycling</i></li> </ul> </li> </ul>

**Table 6: Assessment and Evaluation Tools for Built Environment Sustainability**

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>Materials &amp; Systems</b> <b>Lippiatt &amp; Norris (1995)</b> "BEES"	The Building Community: <ul style="list-style-type: none"> <li>• Designers</li> <li>• Manufacturers</li> </ul>	<ul style="list-style-type: none"> <li>• Environmental Performance</li> <li>• Economic Performance</li> </ul>	<ul style="list-style-type: none"> <li>• Building Materials</li> <li>• Material Life Cycle</li> </ul>
<b>Lawson (1996)</b> "BES Index"	<ul style="list-style-type: none"> <li>• Building councils (local gov't)</li> <li>• Designers/architects</li> <li>• Builders</li> </ul>	<ul style="list-style-type: none"> <li>• Ecological impacts/pollution</li> <li>• Cyclic processes</li> <li>• Waste minimization</li> <li>• Resource depletion</li> <li>• Energy consumption</li> <li>• Inherent Pollution:                             <ul style="list-style-type: none"> <li>• <i>Embodied solid waste</i></li> <li>• <i>Embodied liquid waste</i></li> <li>• <i>Embodied greenhouse gases</i></li> <li>• <i>Embodied toxics/particulates</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Resource depletion:                             <ul style="list-style-type: none"> <li>• <i>Raw material extraction damage</i></li> <li>• <i>Extraction efficiency</i></li> <li>• <i>Resource supply status</i></li> <li>• <i>Recycled content</i></li> <li>• <i>Required maintenance</i></li> <li>• <i>Product recyclability</i></li> </ul> </li> <li>• Embodied Energy:                             <ul style="list-style-type: none"> <li>• <i>Process energy requirements</i></li> <li>• <i>Transport energy</i></li> <li>• <i>Construction energy</i></li> </ul> </li> </ul>
<b>Anink et al. (1996)</b> "Environmental Preference Method"	<ul style="list-style-type: none"> <li>• Architects</li> <li>• Engineers</li> <li>• Contractors</li> </ul>	<ul style="list-style-type: none"> <li>• Shortage of raw materials</li> <li>• Ecological damage of raw material extraction</li> <li>• Energy consumption</li> <li>• Water consumption</li> <li>• Noise and odor pollution</li> <li>• Harmful emissions/ozone depletion</li> <li>• Global warming/acid rain</li> <li>• Health aspects</li> <li>• Risk of disasters</li> <li>• Repairability</li> <li>• Reusability</li> <li>• Waste</li> </ul>	<ul style="list-style-type: none"> <li>• Building Systems</li> <li>• Stone, concrete, brick-like material, and glass</li> <li>• Metals</li> <li>• Synthetics</li> <li>• Wood</li> <li>• Paints</li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<p><b>Howard et al. (1998)</b> "Environmental Profiling System"</p>	<p>Construction industry</p>	<ul style="list-style-type: none"> <li>• Toxicity: <ul style="list-style-type: none"> <li>• <i>Manufacturing</i></li> <li>• <i>Combustion</i></li> </ul> </li> <li>• Primary energy</li> <li>• Emissions: <ul style="list-style-type: none"> <li>• <i>CO2</i></li> <li>• <i>VOCs</i></li> <li>• <i>NOx</i></li> <li>• <i>SO2</i></li> </ul> </li> <li>• Resources: <ul style="list-style-type: none"> <li>• <i>Minerals</i></li> <li>• <i>Water</i></li> <li>• <i>Oil feedstock</i></li> </ul> </li> <li>• Material reserves</li> <li>• Wastes generated</li> <li>• Recycling: <ul style="list-style-type: none"> <li>• <i>% contained</i></li> <li>• <i>% capable of being</i></li> <li>• <i>% currently recycled</i></li> </ul> </li> <li>• Energy required</li> <li>• Cost range</li> <li>• Replacement interval</li> </ul>	<ul style="list-style-type: none"> <li>• High-mass elements: <ul style="list-style-type: none"> <li>• <i>External walls</i></li> <li>• <i>Upper floors</i></li> <li>• <i>Roofs</i></li> </ul> </li> <li>• Medium-mass elements: <ul style="list-style-type: none"> <li>• <i>Windows</i></li> <li>• <i>Interior partitions</i></li> </ul> </li> <li>• Low-mass elements &amp; materials: <ul style="list-style-type: none"> <li>• <i>Wall/roof insulation</i></li> <li>• <i>Floor finishes</i></li> <li>• <i>Doors</i></li> <li>• <i>Floor surfacing</i></li> <li>• <i>Paint systems</i></li> <li>• <i>Ceilings</i></li> </ul> </li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>Anderson &amp; Howard (2000)</b> "Environmental Profiling System"	<ul style="list-style-type: none"> <li>• House builders</li> <li>• Housing designers</li> <li>• Specifiers</li> </ul>	<ul style="list-style-type: none"> <li>• Climate change</li> <li>• Fossil fuel depletion</li> <li>• Ozone depletion</li> <li>• Freight transport</li> <li>• Human toxicity</li> <li>• Waste disposal</li> <li>• Water extraction</li> <li>• Acid deposition</li> <li>• Ecotoxicity</li> <li>• Eutrophication</li> <li>• Summer smog</li> <li>• Minerals extraction</li> <li>• Cost range</li> <li>• Typical replacement interval</li> <li>• Recycled input/Recyclability</li> <li>• Current amount recycled</li> <li>• Energy saved by recycling</li> </ul>	<ul style="list-style-type: none"> <li>• External walls</li> <li>• Roofing</li> <li>• Ground floors</li> <li>• Upper floors</li> <li>• Windows</li> <li>• Internal walls</li> <li>• Kitchens</li> <li>• Refurbishment:               <ul style="list-style-type: none"> <li>• <i>External wall insulation</i></li> <li>• <i>Internal wall insulation</i></li> </ul> </li> <li>• Insulation</li> <li>• Landscaping</li> </ul>
<b>Whole Building</b>			
<b>Cole (1993)</b> "BEPAC"	<ul style="list-style-type: none"> <li>• Trained assessors (consultants)</li> <li>• Designers</li> <li>• Owners</li> <li>• Operators/Managers</li> <li>• Building tenants</li> </ul>	Environmental performance: <ul style="list-style-type: none"> <li>• Ozone layer protection</li> <li>• Energy use</li> <li>• Indoor environmental quality</li> <li>• Resource conservation</li> <li>• Transportation impacts</li> </ul>	<ul style="list-style-type: none"> <li>• Base building design</li> <li>• Base building management</li> <li>• Tenancy design</li> <li>• Tenancy management</li> </ul>
<b>Baldwin et al. (1998)</b> "BREEAM for New Offices"	<ul style="list-style-type: none"> <li>• Government policymakers</li> <li>• Construction professionals</li> <li>• Local authorities</li> <li>• Materials producers</li> <li>• Developers and investors</li> <li>• Environmental groups/lobbyists</li> <li>• Academics</li> </ul>	<ul style="list-style-type: none"> <li>• Management</li> <li>• Health and comfort</li> <li>• Energy</li> <li>• Transport</li> <li>• Water</li> <li>• Materials</li> <li>• Land use</li> <li>• Site ecology</li> <li>• Pollution</li> </ul>	<ul style="list-style-type: none"> <li>• Design</li> <li>• Corporate policies/procedures</li> <li>• Communications</li> <li>• Purchasing/procurement</li> <li>• Contracting out</li> <li>• Facilities/premises mgt.</li> <li>• Space planning</li> <li>• Maintenance</li> <li>• Refurbishm't/recommissioning</li> <li>• Decommissioning</li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>Cole &amp; Larson (1998)</b> "Green Building Challenge/ GBTool"	A/E/C Industry	<ul style="list-style-type: none"> <li>• Resource consumption</li> <li>• Ecological loadings</li> <li>• Indoor environmental quality</li> </ul>	<ul style="list-style-type: none"> <li>• Longevity</li> <li>• Process</li> <li>• Contextual factors</li> </ul>
<b>NAHBRC (1999)</b> "Green Builder Programs"	<ul style="list-style-type: none"> <li>• Home builder associations</li> <li>• Government agencies</li> <li>• Product manufacturers</li> <li>• Public utilities</li> <li>• Non-profits/foundations</li> <li>• Builders</li> <li>• Lenders</li> <li>• Realtors</li> <li>• Developers</li> </ul>	<ul style="list-style-type: none"> <li>• Site development</li> <li>• Energy efficiency: <ul style="list-style-type: none"> <li>• <i>Site</i></li> <li>• <i>Envelope</i></li> <li>• <i>HVAC</i></li> <li>• <i>Appliances/lighting</i></li> </ul> </li> <li>• Resource efficiency: <ul style="list-style-type: none"> <li>• <i>Design</i></li> <li>• <i>Material selection</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Indoor air quality</li> <li>• Waste management</li> <li>• Water efficiency <ul style="list-style-type: none"> <li>• <i>Indoor use</i></li> <li>• <i>Outdoor use</i></li> </ul> </li> <li>• Homeowner opportunities</li> <li>• Business operations</li> <li>• Land development</li> </ul>
<b>U.S. Green Building Council (2000)</b> "LEED"	<ul style="list-style-type: none"> <li>• Architects</li> <li>• Engineers</li> <li>• Contractors</li> <li>• Owners</li> </ul>	<ul style="list-style-type: none"> <li>• Site</li> <li>• Energy &amp; Atmosphere</li> <li>• Water</li> <li>• Materials</li> </ul>	<ul style="list-style-type: none"> <li>• Indoor Environmental Quality</li> <li>• Process</li> <li>• Innovation credits</li> </ul>
<b>Facility + Processes or Whole Development</b>			
<b>Graedel &amp; Allenby (1995)</b> "Industrial Ecology"	<ul style="list-style-type: none"> <li>• Building Owners</li> <li>• Operators/Managers</li> </ul>	<ul style="list-style-type: none"> <li>• Ecology impacts</li> <li>• Biodiversity</li> <li>• Energy use</li> <li>• Solid residues</li> <li>• Liquid residues</li> <li>• Gaseous residues</li> </ul>	<ul style="list-style-type: none"> <li>• Site selection, development, and infrastructure</li> <li>• Business products</li> <li>• Business processes</li> <li>• Facility operations</li> <li>• Refurbishment/transfer/closure</li> </ul>
<b>DuBose &amp; Pearce (1997)</b> "The Natural Step"	<ul style="list-style-type: none"> <li>• Building owners</li> <li>• Designers</li> <li>• Constructors</li> </ul>	<ul style="list-style-type: none"> <li>• Material accumulation: <ul style="list-style-type: none"> <li>• <i>Lithospheric</i></li> <li>• <i>Synthetic</i></li> </ul> </li> <li>• Ecosystem damage</li> <li>• Resource efficiency/fairness</li> <li>• Resource flows into/out of facility</li> </ul>	<ul style="list-style-type: none"> <li>• Facility Life Cycle</li> <li>• Environmental Impact: <ul style="list-style-type: none"> <li>• <i>On site</i></li> <li>• <i>Embodied in resources</i></li> <li>• <i>Resulting from waste disposal</i></li> </ul> </li> <li>• Facility efficiency</li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<p><b>Graham (1997)</b>            "Sustainable Construction and Development Assessment Method"</p>	<ul style="list-style-type: none"> <li>• Academics</li> <li>• A/E/C Industry</li> <li>• Decision makers</li> </ul>	<ul style="list-style-type: none"> <li>• Resources:               <ul style="list-style-type: none"> <li>• <i>Consumption</i></li> <li>• <i>Reuse</i></li> <li>• <i>Energy consumption</i></li> <li>• <i>Appropriate technology</i></li> <li>• <i>Damage to renewable resources</i></li> </ul> </li> <li>• Ecology:               <ul style="list-style-type: none"> <li>• <i>Life support systems conservation</i></li> <li>• <i>Built environment quality</i></li> <li>• <i>Visual impact</i></li> <li>• <i>Biodiversity</i></li> <li>• <i>Interconnectedness of ecology-economics</i></li> <li>• <i>Risk of air, water, or land pollution</i></li> <li>• <i>Bioregional organization</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Humans:               <ul style="list-style-type: none"> <li>• <i>Quality of human life</i></li> <li>• <i>Social self-determination/cultural diversity</i></li> <li>• <i>Distribution of social costs of construction</i></li> <li>• <i>Horizontal control systems</i></li> <li>• <i>Home-based, simpler lifestyles</i></li> <li>• <i>Social and economic change</i></li> <li>• <i>Healthy, non-toxic environment</i></li> <li>• <i>Predetermined goals for management</i></li> </ul> </li> </ul>

**Table 7: Resource Guides to Support Sustainable Building**

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>Bennett (1990)</b> "The Green Pages"	<ul style="list-style-type: none"> <li>• Laypersons</li> <li>• Design professionals</li> </ul>	<ul style="list-style-type: none"> <li>• Non-toxicity</li> <li>• 100% natural content</li> </ul>	
<b>O'Brien &amp; Palermini (1993)</b> "Guide to Resource Efficient Building"	<ul style="list-style-type: none"> <li>• Design Practitioners</li> <li>• Construction Practitioners</li> </ul>	<ul style="list-style-type: none"> <li>• Energy Efficiency</li> <li>• Embodied Energy Efficiency</li> <li>• Environment Protection</li> <li>• Material Efficiency</li> <li>• Health and Safety</li> <li>• Affordability</li> <li>• Competitiveness</li> </ul>	<ul style="list-style-type: none"> <li>• Site Design</li> <li>• Building Size and Shape</li> <li>• Structure and Construction</li> <li>• Safety and Health</li> <li>• Systems</li> <li>• Selling</li> </ul>
<b>Dadd-Redalia, D.L. (1994)</b> "Sustaining the Earth"	<ul style="list-style-type: none"> <li>• Laypersons</li> </ul>	<ul style="list-style-type: none"> <li>• Renewable</li> <li>• Natural/organic</li> <li>• Reused/reusable</li> <li>• Recycled/recyclable</li> <li>• Sustainably harvested</li> </ul>	<ul style="list-style-type: none"> <li>• Energy- or resource-efficient</li> <li>• Nontoxic</li> <li>• Ozone-friendly</li> <li>• Biodegradable</li> <li>• Socially responsible</li> </ul>
<b>Iris Communications (1994)</b> "REDI Guide"	<ul style="list-style-type: none"> <li>• A/E/C Industry</li> <li>• Laypersons</li> </ul>	<ul style="list-style-type: none"> <li>• Energy-saving</li> <li>• Water-saving</li> <li>• Protection against moisture damage</li> <li>• Post-consumer recycled content</li> <li>• Sustainably harvested (forest products)</li> </ul>	<ul style="list-style-type: none"> <li>• Indoor air quality</li> <li>• Low-toxicity</li> <li>• Ozone-friendly</li> <li>• Efficient use of limited natural resources</li> </ul> CSI Masterformat Divisions
<b>Loken et al. (1994)</b> "GREBE"	<ul style="list-style-type: none"> <li>• Owners (residential)</li> <li>• Designers/Architects</li> <li>• Engineers</li> <li>• Materials Specifiers</li> </ul>	<ul style="list-style-type: none"> <li>• Resource efficiency</li> <li>• Use of recycled materials</li> <li>• Energy savings in mfg.</li> <li>• Durability</li> <li>• Dimensional lumber alternatives</li> <li>• Landscaping</li> <li>• Job Site Recycling</li> <li>• Foundations</li> </ul>	<ul style="list-style-type: none"> <li>• Framing and Panel Systems</li> <li>• Enclosures:                             <ul style="list-style-type: none"> <li>• <i>Sheathing &amp; Wallboard</i></li> <li>• <i>Roofing</i></li> <li>• <i>Exterior Siding &amp; Trim</i></li> <li>• <i>Insulation</i></li> <li>• <i>Windows &amp; Doors</i></li> </ul> </li> <li>• Interior Finishes:                             <ul style="list-style-type: none"> <li>• <i>Floor Coverings</i></li> </ul> </li> </ul>

SOURCE	TARGET AUDIENCE	BUILT ENVIRONMENT SUSTAINABILITY VARIABLES	
<b>St. John (1994)</b> "Sustainable Design Guide"	<ul style="list-style-type: none"> <li>• Designers/Architects</li> <li>• Materials manufacturers</li> </ul>	<ul style="list-style-type: none"> <li>• Consensus of endorsement</li> <li>• Environmental responsibility</li> <li>• Benign substitution</li> <li>• Recycled content</li> </ul>	CSI Masterformat Divisions
<b>Hermannsson (1997)</b> "Green Building Resource Guide"	<ul style="list-style-type: none"> <li>• Builders</li> <li>• Architects</li> <li>• Homeowners</li> </ul>	<ul style="list-style-type: none"> <li>• Nontoxicity/indoor air quality</li> <li>• Recycled content</li> <li>• Resource efficiency</li> </ul>	<ul style="list-style-type: none"> <li>• Long life cycle</li> <li>• Environmentally conscious</li> </ul> CSI Masterformat Divisions
<b>Holmes et al. (1999)</b> "GreenSpec"	<ul style="list-style-type: none"> <li>• Architects</li> <li>• Contractors</li> <li>• Building managers</li> <li>• Homeowners</li> </ul>	<ul style="list-style-type: none"> <li>• Resource utilization:               <ul style="list-style-type: none"> <li>• <i>Abundance of resource</i></li> <li>• <i>Replacement/replenishment</i></li> <li>• <i>Efficiency of resource use</i></li> <li>• <i>Efficient use of associated resources</i></li> <li>• <i>Durability of material</i></li> <li>• <i>Recycled content</i></li> <li>• <i>Recyclability</i></li> </ul> </li> <li>• Energy:               <ul style="list-style-type: none"> <li>• <i>Embodied energy</i></li> <li>• <i>Conservation of energy during operation</i></li> </ul> </li> <li>• Solid waste:               <ul style="list-style-type: none"> <li>• <i>Landfill diversion</i></li> <li>• <i>Reuse of materials/components</i></li> <li>• <i>Solid waste avoidance</i></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Pollution - air and water:               <ul style="list-style-type: none"> <li>• <i>Global warming (CO<sub>2</sub>, fossil fuel emissions)</i></li> <li>• <i>Ozone depletion</i></li> <li>• <i>Indoor air quality (VOCs, dust, mold, etc.)</i></li> <li>• <i>Heavy metals/toxins</i></li> <li>• <i>Biocides/pesticides</i></li> </ul> </li> <li>• Habitat destruction:               <ul style="list-style-type: none"> <li>• <i>Water</i></li> <li>• <i>Soil</i></li> <li>• <i>Biodiversity</i></li> <li>• <i>Erosion/silt</i></li> <li>• <i>Noise</i></li> </ul> </li> </ul> CSI Masterformat Divisions

## **Figure Captions**

**Figure 1:** Classes of Knowledge Representation [15]

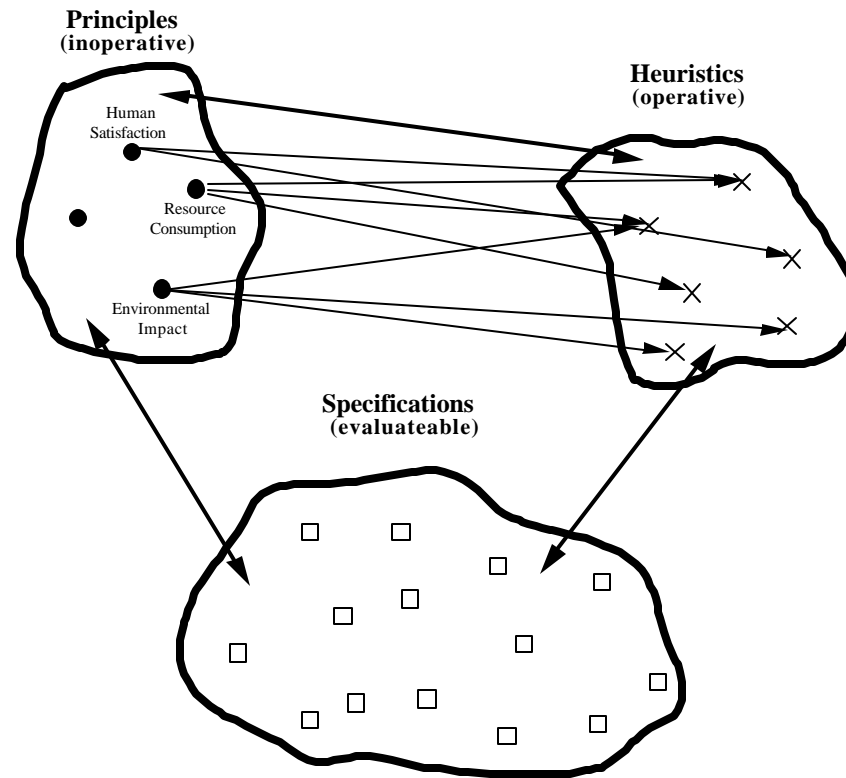
**Figure 2:** Relative Frequency Distribution of Heuristics [40]

**Figure 3:** Stakeholder Groups Targeted by Sources Analyzed in the Study

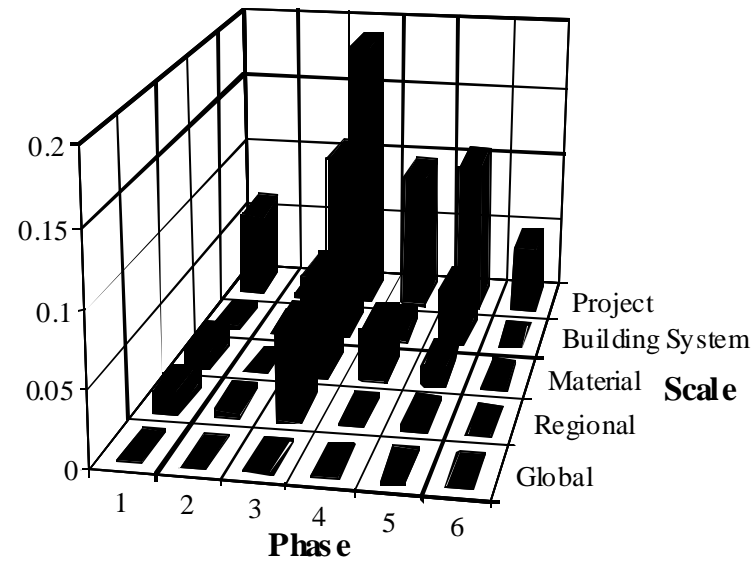
**Figure 4:** The Evolution of Knowledge about Sustainability [64]

**Figure 5:** Moving from the Point of Departure to Operationalization [65]

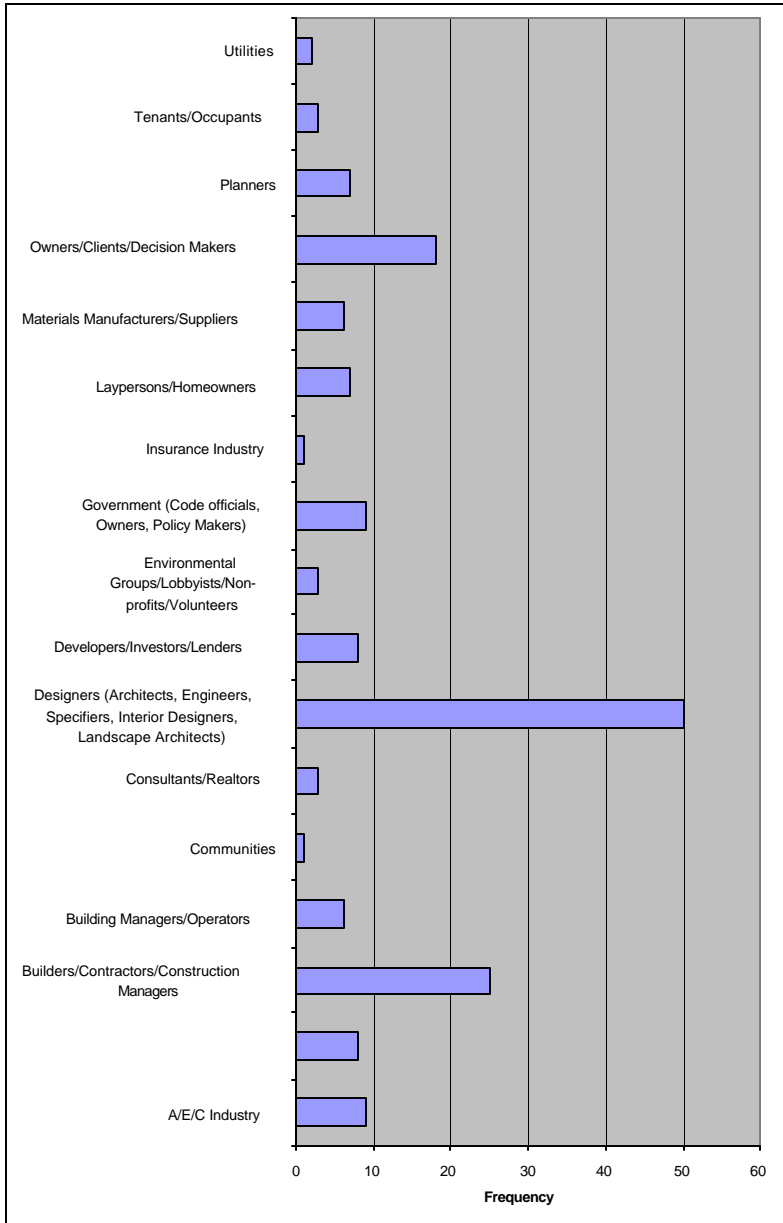
## Figures



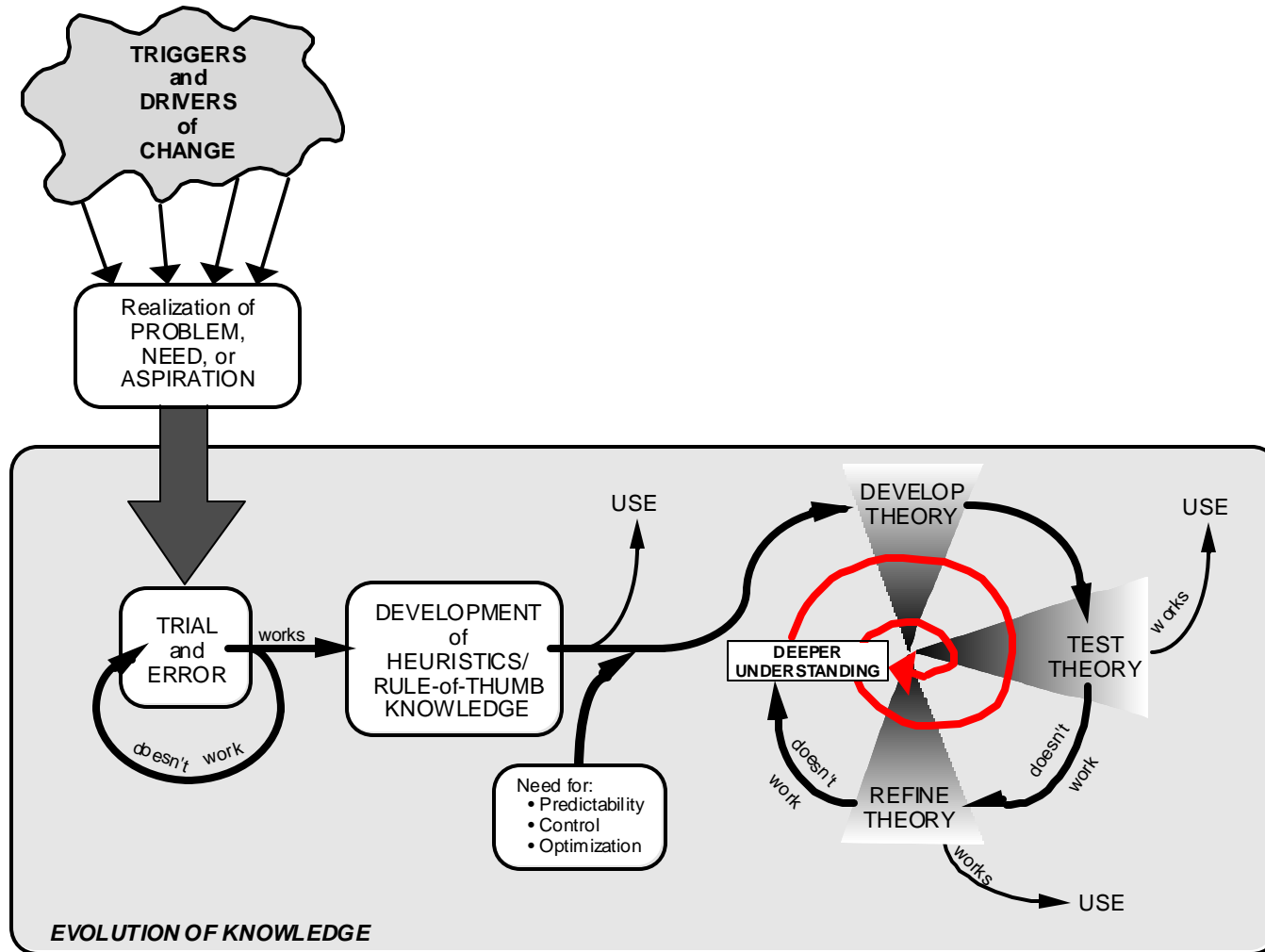
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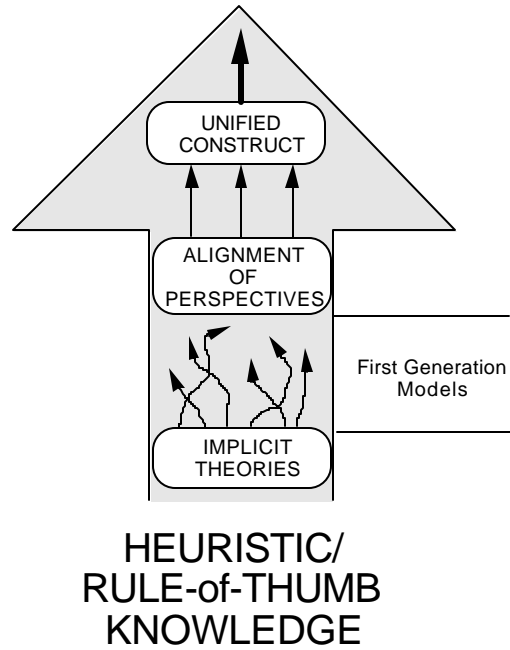


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**Figure 4:** The Evolution of Knowledge about Sustainability [64]

# OPERATIONALIZATION



**Figure 5:** Moving from the Point of Departure to Operationalization [65]