Green Building & Human Experience

Testing Green Building Strategies with Volunteered Geographic Information

Chris Pyke[1], Sean McMahon, Tom Dietsche
U.S. Green Building Council®

Research Program White Paper

June 10, 2010

[1] Corresponding author: Dr. Chris Pyke, Director, Research, 2101 L St, NW, Suite 500, Washington, DC 20037. cpyke@usgbc.org.

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Introduction

Built environments often define the fabric of our communities and play a central role in physical and psychological health. Today, the majority of empirical data collection in built environments focuses on physical attributes and environmental performance, such as energy or water consumption. We are building increasingly sophisticated systems to collect, analyze, and use information on building energy consumption; information networks that soon will stretch from the power plant to a Smart Meter and, in some cases, to a Smart Phone. This creates unprecedented opportunities to manage energy use and improve energy efficiency. While the volume of information about energy and, to a lesser degree water, is growing rapidly, information about the experience of people in and around built environments lags far behind.

The relevant dimensions of human experience encompass traditional notions of occupant productivity, comfort, and satisfaction, as well as related concepts of walkability, well-being, connectivity, community, and social capital (Dearry 2004).   In an attempt to better understand these concepts, and develop a framework for the sustained collection of data on actual human experience within the built environment this paper explores the intersection between three important concepts:

- Human experience;
- Volunteered Geographic Information (VGI); and
- Green building.

Our goal is to explore opportunities to test strategies with practice-based experiments. We believe that this is part of a larger effort to advance the green building community toward "evidence-based practice based on practice-based evidence" (Simons et al. 2003).

Human Experience

Our basis for understanding these aspects of human experience largely remains tied to traditional survey methods. We use paper or web-page forms to ask people what they think and how they feel. With skill and proper experiment design, this approach yields important insights. However, this approach requires substantial investment in each new data point, and it offers few opportunities to create the kind of pervasive, readily-scalable types of data we will soon use to understand phenomena such as energy and water use. For example, industry and academic researchers have begun to envision an "energy ecosystem" driven by pervasive information about energy supply and demand (Arnold and Cochrane 2009). Major technology companies are rushing to provide residential and commercial consumers with new types of information systems, many of which provide the foundation of a coming generation of energy savings applications and products (e.g., Microsoft Hohm, Google PowerMeter, and Apple's Smart Home Energy Management System). A similar vision has yet to emerge for understanding the experience of humans in and around built environments.

Asymmetries between our understanding of human experience and issues such as energy are not the result of chance or intrinsic value. They reflect long-standing patterns of attention and investment in research and development. A review of federal research and development funding related to green building for the period 2002-2005 found that energy-related research received 72% of available funding, while indoor environmental quality-related research received only 2% of funding (Baum 2007). This allocation of resources belies the actual

drivers of operational costs and business value associated with buildings. Studies repeatedly find that human resources comprise the majority of total expenses associated with office buildings. For example, Romm (1994) found that personnel constitute 92% of operating expenses, while Californa's Department of General Services (2002) estimated 89%. A slowly growing body of case studies over the past 20 years illustrates the potential benefits to our human resources (individual and societal, financial and otherwise) from better buildings and communities (e.g. Kaplan 1989, Browning 1994, Milton 2000, Fisk 2000, Kats 2003, Kats 2010, Carnegie Mellon University). Even modest improvements in productivity, absenteeism, and/or employee retention can substantially outweigh the traditionally sought-after efficiency benefits such as energy savings. These are mirrored by significant potential health and wellness benefits, such as reductions in exposure to toxic substances and improvements in physical activity levels.

These persistent trends contribute to a situation where information on energy and environmental performance dwarf relevant information about factors related to occupant experience and health outcomes. This imbalance undermines efforts to establish evidence-based feedbacks to improve green building guidelines and, ultimately, advance green building practice. Recognizing this imbalance does not question the critical importance of energy and water; however, it does call for a conscious effort to establish a more balanced foundation of information on building performance that reflects both people and the environment.

The bottom line on human experience is that we are systematically under-investing in the most valuable aspect of buildings, occupant experience. As a result, we know less than we should about human experience in and around built environments. In turn, we have less evidence to demonstrate that green building practices enhance human experience. This feeds a cycle where we under-invest in high-performance projects, because we lack data on the performance of high-performance projects (Nelson 2010).

> **Importance of Human Experience**
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> Human experience is one of the most critical barometers of the success of a built environment. Traditionally, human experience in and around built environments has been evaluated through surveys, interviews, and, in some cases, direct observations. These tried-and-true methods yield important insights, but they are not readily scalable or spatially extensible. Every observation requires substantial investments in time and energy and is difficult to generalize and iterate. We need new, scalable sources of information and systematic feedback processes to help advance consideration for occupant experience as a part of evidence-based green building practice.

Volunteered Geographic Information

Volunteered Geographic Information (VGI) is a term popularized in the geographic information science community[2]. It encompasses concepts, methods, and technologies that allow individuals to collect and convey data about spatially and temporally distributed phenomena. It has been enabled by on-going advances in both mobile computing hardware, such as sensors and hand-held devices, and software, such communications protocols, middleware, and advanced server technology. It is now possible to use off-the-shelf technology to create mobile devices that track location, measure physical activity, monitor physiological conditions (e.g., heart rate), and allow for synchronous and asynchronous communication.

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[2] http://www.ncgia.ucsb.edu/projects/vgi/

Successful examples of VGI include citizen science programs such as the long-running Christmas Bird Count[3] or the school-based, environmental science program Project GLOBE[4]. In both examples, volunteers follow explicit protocols to make repeated measures of environmental or ecological conditions. These spatially and temporally specific data are combined in central repositories and used for a wide-variety of scientific research. Both programs have yielded significant scientific findings. Advances in sensors, information technology, and social networking have led some to suggest that we are ready for a breakthrough in the scale and impact of such efforts (Goodchild 2007).

VGI is particularly compelling for the building sector where long-running debates about data confidentiality have stifled progress towards creating large, accessible data sets. As we have discussed in the preceding section, this contributes to a pervasive lack of information, particularly about human experience. VGI illustrates it is possible to make significant scientific progress by focusing on actions that willing individuals can take to contribute data that addresses important scientific questions. The most successful applications bring together accessible and robust technology, effective forms of interpersonal engagement and reward, and thoughtful experiment design.

VGI offers the potential to, at least temporarily, put aside long-running arguments about data disclosure mandates (McNeill and Wilkie 1979) and make significant progress through systematically-organized networks of self-motivated data providers. In concept, a similar principle underlies USGBC's on-going *Building Performance Partnership[5]*. In the BPP program, project teams volunteer to provide information on energy and water performance for LEED certified facilities. This further demonstrates their leadership and commitment to green building, while contributing a small piece of data that advances the vision of effective market transformation. As with most VGI-based efforts, the BPP program combines accessible information technology (US EPA's Portfolio Manager), social networking and peer recognition, with a systematic strategy to collect relevant data across a target population. There is an untapped opportunity to complement this work with a focus on human experience, including outcomes linked to health, comfort, and satisfaction.

Importance of Volunteered Geographic Information

In the past, geographic information was scarce and expensive. It required investments by governments and other large institutions to collect, compile, and distribute information such as maps and, later, imagery. Over the past decade, we have witnessed the emergence of new technologies that empower individuals acting together to readily create valuable information about the world. This represents a dramatic shift in how information is produced and, ultimately, how it informs practice.

Green Building

Green building is a systematic effort to create, sustain, and accelerate changes in practice, technology, and behavior to reduce building-related environmental impacts while creating places that are healthier and more satisfying for people. In the United States, green building has largely emerged from communities of practitioners working to define beneficial processes and practices and create mechanisms to recognize and

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[3] http://www.audubon.org/bird/cbc/

[4] www.globe.gov

[5] http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2201

encourage their use. Today, the U.S. Green Building Council realizes this vision with a combination of processes and tools, including consensus-based rating systems, rigorous third-party review and certification, and educational resources. One of the most important tools is the Leadership in Energy and Environmental Design (LEED) green building certification program. LEED® rating systems include a combination of required prerequisites and elective credits. Here we refer to these elements collectively as green building strategies. Each strategy has a clearly defined intent that describes the desired outcome. Each intent is crafted by teams of volunteers and subjected to multiple rounds of public review and comment. Each credit provides one or more options for specific strategies that can achieve its intent, and each option is associated with specific required documentation. During the certification process, documentation is provided to an independent review body which ultimately determines whether each strategy meets LEED requirements.

Requirements for LEED certification are not static. Rather, they reflect an explicit commitment to "raising the bar" toward an ultimate goal of regenerative built environments – buildings and communities that actually improve conditions for people and the environment. Change is often manifested in the details of the rating system with new documentation requirements or so-called alternative compliance paths. Credit intents represent the most stable aspect of the system; they reflect a high-level aspiration that, in practice, may be fulfilled in many different ways.

 Current green building processes and practices have been successful in promoting the use of specific strategies during planning, design, construction, and operation of neighborhoods, new construction, and existing buildings. This success is reflected in over 130,000 trained, accredited professionals and nearly 5,000 certified projects with another 20,000 in the process of pursuing certification. Each of these projects contains a distinct, sometimes unique, combination of green building strategies. Each strategy achieved by every certified project is recorded with USGBC and potentially available for analysis. Each project is also associated with a project team, typically including a LEED Accredited Professional. Each LEED AP® has demonstrated a familiarity with green building concepts and, at minimum, possesses a working vocabulary to describe important aspects of building performance and experience.

Ultimately, LEED provides a number of important elements to the confluence of human experience and VGI. LEED brings explicit aspirations or intents for individual green building strategies, verification of the implementation strategies on specific projects, and a cadre of trained professionals.

Importance of Green Building

Green building is a movement dedicated to the transformation of practice in the design, construction, and operation of built environments. The objective is to reduce the negative impacts of built environments while creating healthy, comfortable, and economically prosperous places for people to live, work, and play. The popular term "green building" encompasses the collection of processes, institutions, and individuals that serve to assess current practice, identify opportunities for improvement, develop and deploy tools, and provide independent review and recognition of results. The green building community has diversified from its origins in the architecture and engineering professions to encompass the full range of professionals involved in lifecycle of built environments.

Applying VGI to Evaluate Green Building Strategies related to Human Experience

We believe that it is possible to appreciate the current state of practice and develop research programs that strive to address these issues and create real and systematic connections between concepts, green building practice, and evidence-based evaluation. This involves creating the foundation of data needed to critically evaluate green building strategies as testable-hypotheses. Each project has the potential to contribute a sample to a large scale experiment in the efficacy of green building strategies. With over 5,000 certified projects and tens of thousands more on the way, the potential exists for powerful, real world tests.

Realizing this vision requires integrating green building rating certification processes with systems to combine data, analyze results, and ultimately create useful information about the effectiveness of different strategies. Such iterative processes of continuous improvement underlie many successful enterprises (e.g., the Deming Cycle of plan, do, study, act). In the health sciences, such processes may be described as evidence-based practice. In the environmental sciences, they might be referred to as adaptive management. The green building community has begun the process of creating and operationalizing such systems for key environmental impacts, particularly energy and water consumption. However, systematic attention to human experience and health outcomes as explicitly testable phenomena lags behind.

We believe the convergence of factors described above creates the potential for building occupants to literally act as sensors with their personal experiences providing data that can be used to evaluate the success of green building strategies. We now have the ability to turn the experience of space into data on the consequences of that experience, such as physical activity, chemical exposures, comfort, even happiness. The challenge is to develop the concepts and methods needed to turn these emerging information technologies into systematic tools to inform and improve green building practice.

> **Integration**
> Understanding human experience in built environments is a complex business. New sensors and information technologies create unprecedented opportunities, but they are not sufficient in and of themselves. The real challenge is to create and deploy a scalable hierarchy of methods that include timely and relevant questions, rigorous experimental design, traditional survey- and interview-based methods, existing and emerging sensors, and cutting-edge information technology. In this context, the science of technology is enabled (or constrained) by the arts of systems architecture and experimental design.

Green Building Strategies Related to Human Experience

As we begin to consider the opportunities created by these new approaches and technologies, it is important to ask what kinds of questions can be answered about "occupant experience". A preliminary analysis[6] of three widely-used LEED rating systems suggests that from a quarter to almost half of credits can potentially be evaluated using information about occupant experience. In other words, for these credits we believe that is possible, and in some cases necessary, to use information on human experience to determine whether implementation of a strategy fulfills the intent of the credit.

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[6] All figures are based on a preliminary but thorough analysis. Innovation in Design, Innovation in Operations, Innovation and Design Process, and Regional Priority credits are not included in calculations.

The fraction of credit intents that can be addressed with information on human experience varies between rating systems. This is to be expected since the systems focus on different market segments and different periods in the lifecycle of built environments. Surprisingly, the smallest fraction of testable credits was found in the LEED for Existing Buildings: Operations & Maintenance™ rating system with only 25% of credit intents directly related to human experience. Conversely, 42% of credit intents in LEED for Neighborhood Development™ could be evaluated using information on human experience.

Opportunities to test credit intents also vary by credit category. In LEED for New Construction™ and LEED for Existing Buildings: O&M, the majority of testable opportunities related to Indoor Environmental Quality (IEQ). This includes 82% of IEQ credits in LEED for New Construction and 67% of IEQ credits in LEED for Existing Buildings: O&M. These IEQ strategies relate to occupant control, comfort, and satisfaction. LEED for Neighborhood Development's Neighborhood Pattern & Design (NPD) credit category had the greatest fraction of potentially testable strategies representing approximately 89% of credits. These LEED for Neighborhood Development strategies relate directly to experience in and around neighborhoods, such as the provision of safe and comfortable streets and access to a diverse range of community services, including schools, shops, parks and public transport.

Figure 1(a): Preliminary analysis of the distribution of testing methods for LEED for New Construction (NC), LEED for Existing Buildings: O&M (EB), and LEED for Neighborhood Development (ND) credits. Y-axis represents the fraction of LEED credit intent that may be addressed by Volunteered Geographic Information (VGI), building performance information (BPI), "not testable" by either VGI or BPI.
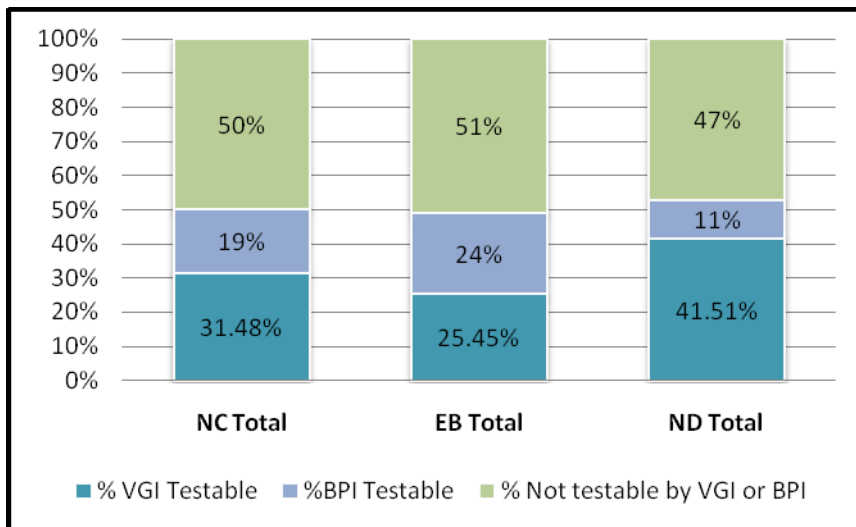
Figure 1(b): LEED for Neighborhood Development. Y-axis represents the fraction of LEED credit intent that may be addressed by Volunteered Geographic Information (dark blue), building performance information (purple), "not testable" by either VGI or BPI (green). X-axis categories include Smart Location and Linkage (SLL), Neighborhood Pattern and Design (NPD), and Green Construction and Technology (GCT).
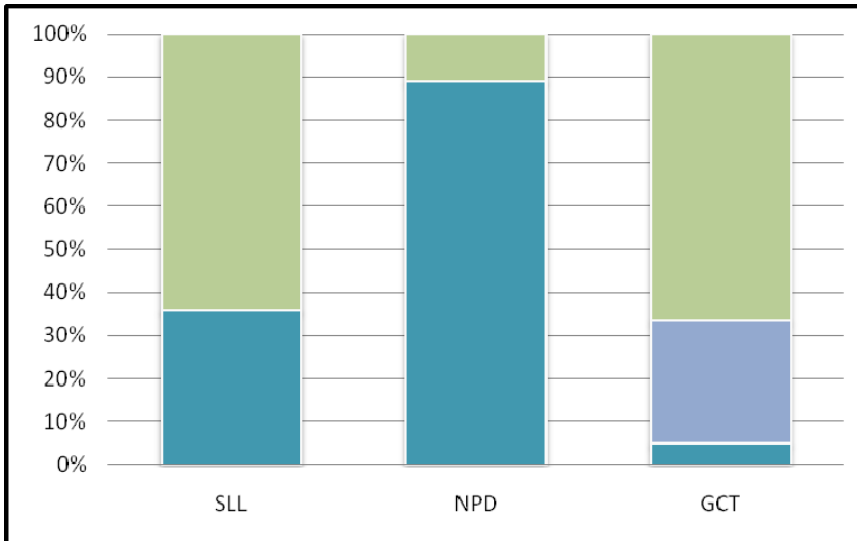

Figure 1(c): LEED for New Construction. Y-axis represents the fraction of LEED credit intent that may be addressed by Volunteered Geographic Information (dark blue), building performance information (purple), "not testable" by either VGI or BPI (green). X-axis categories include Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), and Indoor Environmental Quality (IEQ).
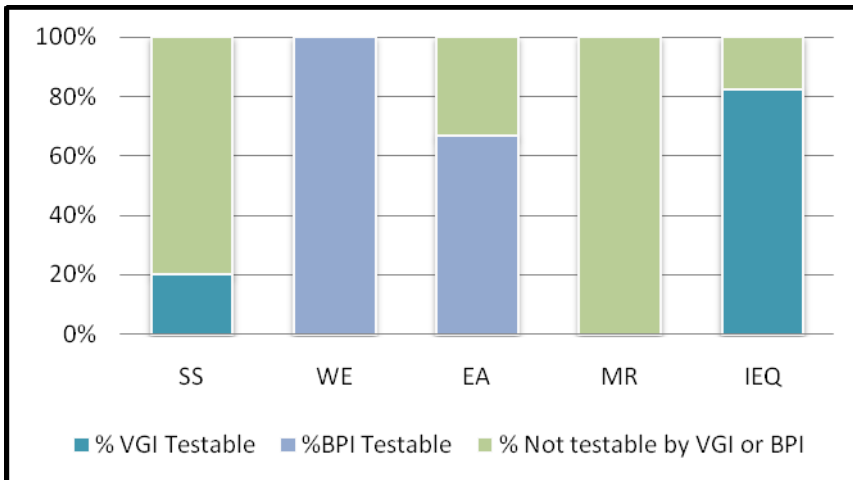
Figure 1(d): LEED for Existing Buildings. Y-axis represents the fraction of LEED credit intent that may be addressed by Volunteered Geographic Information (dark blue), building performance information (purple), "not testable" by either VGI or BPI (green). X-axis categories include Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), and Indoor Environmental Quality (IEQ).
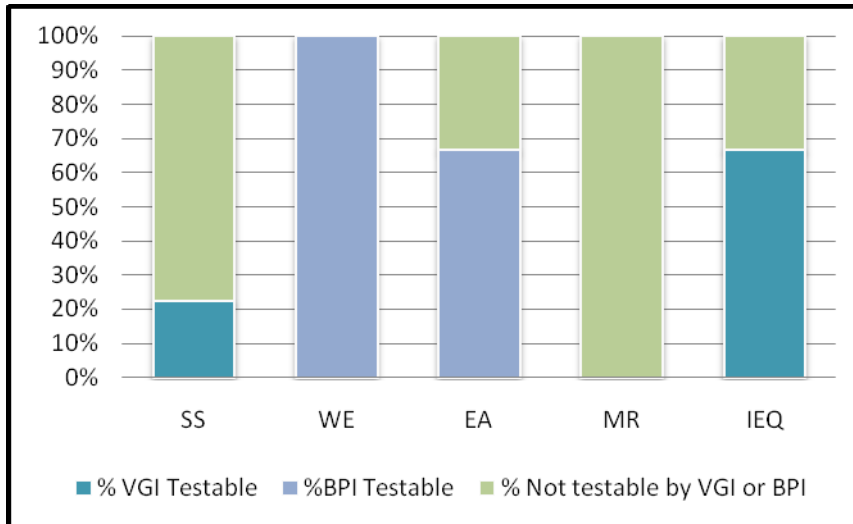
We also note that information based on human experience specifically addresses strategies that are not currently captured by monitoring energy or water use. As illustrated above, nearly 70% of Energy & Atmosphere (EA) and 100% of Water Efficiency (WE) credits can be evaluated to some degree by analyzing utility bills, or through the use of technology such as Smart Meters. The same cannot be said of the Sustainable Sites (SS), Indoor Environmental Quality (IEQ), or Neighborhood Pattern & Design (NPD) credit categories for which no analogous method of scalable data collection and evaluation is currently in practice. While a steady stream of information on building energy and water use is unquestionably valuable, these strategies represent only 11% (LEED for Neighborhood Development), 19% (LEED for New Construction), and 24% (LEED for Existing Buildings: O&M) of available credits. In total, this represents approximately 18% of the credits across the three surveyed LEED rating systems. Conversely, nearly 33% of credits are potentially testable using VGI to collect information relating to occupant experience (Figure 2).

This illustrates that sustainable, scalable flows of information about occupant experience are an essential complement to other data on building performance. The use of VGI to record actual human experience within the built environment offers a tremendous opportunity to fill this gap, while also evaluating the effectiveness of green building strategies in improving the health, safety, and well-being of occupants.

Figure 2(a): Cumulative Totals - LEED for New Construction, LEED for Existing Buildings, and LEED for Neighborhood Development Testable Credits. Y-axis represents the fraction of LEED credit intent that may be addressed by Volunteered Geographic Information (blue), building performance information (red), "not testable" by either VGI or BPI (green).
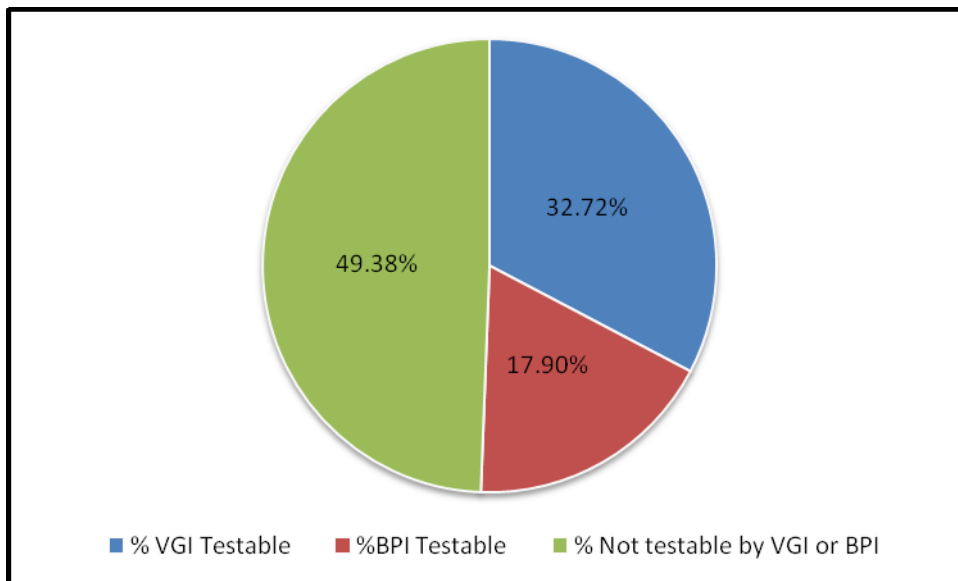
Next Steps

This paper describes some of the elements of a new vision for broad, spatially and temporally extensive data on human experience in built environments coupled with iterative processes to drive improvement in green building practice. We believe that we can make immediate progress by targeting specific green building strategies which lend themselves to demonstration of these concepts, such as:

Walkability. Strategies in LEED for Neighborhood Development include detailed prescriptions for street and sidewalk design to promote "walkability". These requirements are based on significant scientific literature; however, these form-based predictions essentially represent testable hypotheses about how people will experience these streetscapes.

Question:	Do people actually experience streets as "walkable"?
Green building intent:	Promote walking as a mode of transportation.
Human experiences:	Perceive space as walkable; increase walking; higher levels of physical activity
VGI strategy:	Query occupant about perceptions and activity levels while they are in and around the area.

Diverse land uses. Every LEED rating system has some version of strategies to recognize and reward strategies that promote land use diversity. The intent is typically to encourage pedestrian access to services and reduce use of automobiles. For example, LEED rewards projects for having a certain number of land uses within a certain distance of a project.

Questions:	Do people actually experience areas around LEED projects that achieve these credits as diverse and connected? Do they use these services? Do they walk to them?
Green building intent:	Promote dense, connected communities; promote walking as a mode of transportation.
Human experiences:	Perceive communities as diverse, vibrant, and connected; use local services to meet their needs.
VGI strategy:	Query occupant about perceptions and activity levels while they are in and around the area.

Occupant Comfort. Green building includes a number of strategies that are intended to work together to create and sustain healthy, comfortable indoor environments. As with neighborhoods, these green building strategies are most often prescriptive or form-based metrics, such as measures of access to daylight or ventilation rates. The traditional method of data collection is the occupant survey. Surveys have been used effectively to understand occupant experience; however, this device typically lacks the ability to provide spatial and temporal detail.

Questions:	Do occupants of projects that utilize strategies to promote indoor environmental quality actually experience that space as healthier and more comfortable?
Green building intent:	Provide comfortable, satisfying, and productive spaces for occupants.
Human experiences:	Perceive spaces as comfortable and healthy; increase productivity, reduce complaints, and improve health outcomes.
VGI strategy:	Query occupant about perceptions and activity levels while they are in and around the area.

Conclusion

We have an opportunity to shift green building from the implementation of Best Practices toward an evidence-based practice based on practice-based evidence.   This transition will require us to identify opportunities to adapt technology to better serve the purpose of understanding human experience in ways that create systematic information that can be combined with traditionally-collected data and emerging sensor technology. Taken together, a sustained, integrative approach to understanding people, information, analytics, and practice can help drive market transformation in ways that increase the prevalence of practices that demonstrably improve human experience in built environments.

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