Eco-Effective Design and Evidence-Based Design: Removing Barriers to Integration

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INTRODUCTION

Evidence-based design (EBD) and eco-effective design (EED) are very pertinent to healthcare design today, as both push to achieve increased or improved positive outcomes in human and/or environmental health. Eco-effective design gives rise to buildings that generate improved ecological health and indoor environmental quality (McDonough Braungart Design Chemistry [MBDC], 2008). Evidence-based design gives rise to buildings that generate positive health outcomes in hospitals through a growing body of best practice strategies that are informed by research and practical knowledge (Hamilton, 2003). Eco-effective and evidence-based design are two trends that are significantly impacting healthcare architecture today (Shepley, Baum, Ginsberg, & Rostenberg, 2009). Although both movements have directly impacted recent healthcare architecture (Klein, 2007), they are often implemented separately, and some consider them to be in conflict with one another (e.g. Harvie, 2006; Teske & Mann, 2007). This study intends to better understand the intersections between these two trends, and how successful hospitals have and are incorporating and measuring them.

Language

This research sprung from a need to understand the intersections between evidence-based design and sustainability. William McDonough and Michael Braungart coined the term “eco-effective” and define it as "the strategy for designing human industry that is safe, profitable, and regenerative, producing economic, ecological, and social value" (MBDC, 2008). The philosophy of sustainable design, on the other hand, is driven by the need to address problematic outcomes

resulting from standard construction practices during and following the industrial revolution. Sustainable development is defined in the 1987 Brundtland Report as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). In other words, sustainable development is development that doesn't cause future problems. Simply put, the focus of "eco-effective," in contrast to that of sustainable or "eco-efficient," focuses on the creation of more good impacts of buildings rather than reducing negative impacts.

The eco-effective approach of creating positive environmental impacts has a stronger relationship to the goals of healthcare than do the approaches commonly associated with sustainability. Eco-effective design and evidence-based design both strive to create increased positive outcomes, not fewer negative ones. Others have put forward that regenerative design, similar to eco-effective design, is the appropriate goal for healthcare architecture (e.g. Guenther & Vittori, 2008; Mah, Guenther & Pierce, 2008). Regenerative design is a systems-thinking approach to design that suggests that the outcome of a built project provides more resources or benefit than those which were required for the construction process or pre-exised on the site, thus restoring and revitalizing environmental conditions (Lyle, 1996).

Given the philosophical alignment between eco-effective design and evidence-based design, the principal investigators chose to use eco-effective design over sustainable design as the focus for this research. However, the language of sustainability and sustainable design is comparatively prevalent outside of the profession of architecture. For the purpose of communicating with a lay audience, the principal investigators used the term "sustainable design" to help explain eco-

effective design. The communication was structured such that the use of one phrase over the other would not alter the results.

METHODS

The research was approached through a series of phases in which the outcomes from each phase provided input for subsequent phase(s).

Phase 1: Advisory Groups. In the first phase, researchers convened advisory groups made up of experts on evidence-based design and eco-effective design with Anshen+Allen Architects. The advisory groups provided direction on the critical questions on the relationship between EBD and EED that would be addressed in the EBD-EED Survey. The advisory groups also identified names of national EBD and EED experts as well as built healthcare projects that they considered to represent "centers of excellence" in EBD and/or EED. The principal investigators augmented these lists of experts and facilities with additional projects identified through a literature review. Advisory group members also provided feedback as needed in other phases of the research.

Phase 2: Best Practice Facility Survey. In the second phase, researchers surveyed national experts in EBD and EED to identify the best of the EBD and EED centers of excellence. Twenty-six experts in each area were emailed a list of projects identified in the first phase. The national experts were asked to identify the top 10 built facilities in North America representing best practice in either EBD or EED hospitals. EED experts were only asked to consider EED

projects, and EBD experts were only asked to consider EBD projects. The researchers used the results of this survey to identify best practice facilities to be surveyed in Phase 3.

Phase 3: EED-EBD Survey. In the third phase, the researchers surveyed healthcare administrators at the facilities identified in Phase 2. The administrators had been involved with or were aware of the design processes and are currently involved with the operation of the facilities. The administrators were emailed a 22 question Likert and narrative-response survey with the option of answering either by email, phone or fax.

Phase 4: Literature Review. In the fourth phase, researchers conducted a literature review on each of the facilities whose administrators responded to the Phase 3 survey plus sources that address EBD and EED outside the context of a specific building. The research team reviewed over 130 items from a variety of resources: trade publications, newspaper articles, press releases, interviews, popular magazines, books, case studies, white papers, and peer reviewed journal publications. The majority of the articles were not peer-reviewed; as such, they only suggest the quantity and quality of knowledge available to professionals engaged in healthcare architecture. The research team focused on anecdotal and perception-based content that reveals the general zeitgeist around the issues of EBD and EED for healthcare construction.

Phase 5: Strategy Matrix. A spreadsheet matrix of strategies was developed in order to map relationships between specific EBD and specific EED strategies. EBD strategies were listed in columns, with EED strategies listed in rows -- the intersection between each EBD and EED strategy was marked with a symbol representing the nature of the relationship. Solid red and

green circles indicated clear conflicts and clear synergies respectively. Open red and green circles indicated possible conflicts and possible synergies. An open black circle indicated a connection between the two strategies, but not one that would directly elicit a conflict or synergy. A combination of red and green circles indicated conditions at which both conflicts and synergies might occur simultaneously.

The research team compiled lists of EBD and EED strategies from various sources, then merged and refined them for organizational and conceptual clarity. The EED strategies came primarily from the Leadership in Energy and Environmental Design (LEED®) and Green Guide to Healthcare (GGHC™) rating systems for new construction and operations, though a few are best practices not included in those sources. These systems present a clear taxonomy that is generally accepted by the profession. EED strategies in the matrix are divided into six main categories: Sustainable Sites; Water Efficiency; Energy & Atmosphere; Materials & Resources; Indoor Environmental Quality; and Operations. In comparison, EBD strategies are not organized or defined in one uniform structure across the industry. The EBD categories used in the matrix were derived from EBD advisory group members and from several print sources, including the Center for Health Design's various resources and the book A Visual Reference for Evidence-Based Design (Center for Health Design, 2004 & 2008) (Malkin, 2008). The EBD matrix categories are: Healthy Experience; Safety; Operational Efficiency; Technology; and Life Cycle Flexibility.

The matrix was filled out separately by four individuals or pairs of people; each person or pair represented expertise in both EBD and EED. The four matrices were compiled into a single final

matrix. A principal investigator met with each of the groups regularly to fully understand the nature of their responses and to maintain consistency and clarity.

FINDINGS

Best Practice Facility Survey and EED-EBD Survey

The EBD and EED experts identified 9 EBD and 9 EED facilities that are representative of best practice in each subject area. The hospitals are distributed around all regions of the United States and represent a range of sizes and programs. Most are inpatient hospitals, although three are outpatient clinics. Two of the facilities also include research laboratories in addition to clinical space. Six of the 18 facilities either have obtained or are pursuing a Leadership in Energy and Environmental Design for New Construction (LEED® NC) Rating; the facilities have collectively acquired all possible levels of LEED® Certification: Certified, Silver, Gold and Platinum.

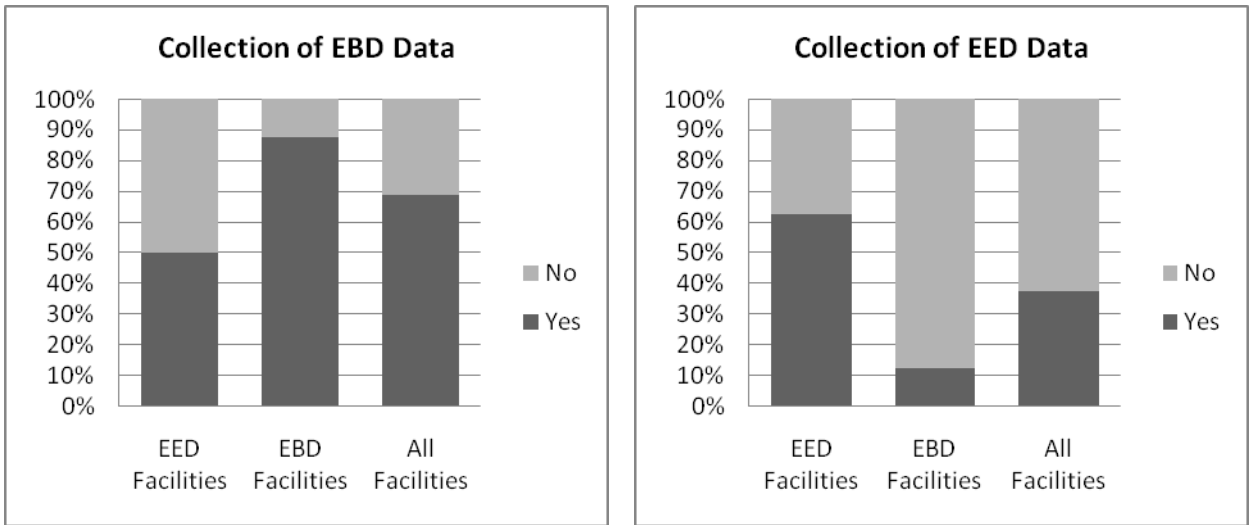
Of the administrators surveyed, 8 from each facility type responded. The survey responses suggest that overall, EBD and EED are compatible, although some specific strategies may be in conflict. These findings are discussed in greater detail in an 2009 article in *Health Environments Research and Design* (HERD), including the role of EBD and EED in facility design and operations as well as perceptions on the relationships between EBD and EED strategies (Shepley et al, 2009). This article instead focuses on the role of EBD and EED data collection in

the best practice facilities, on lessons learned provided by the healthcare administrators, plus the literature review and strategy matrix.

Facility Data Collection

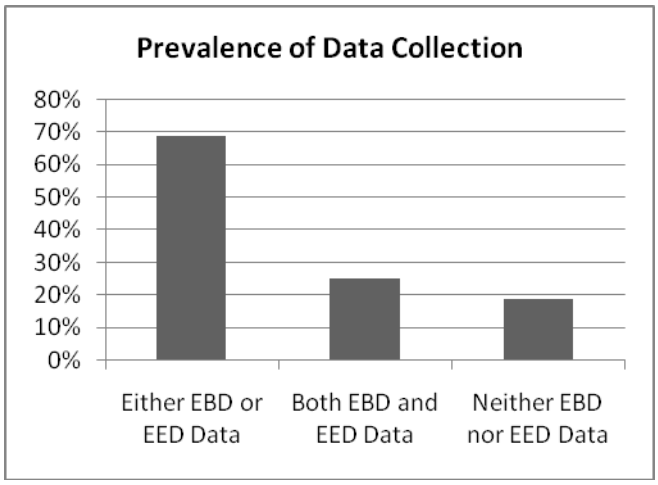
Overall, more hospitals are collecting data on EBD metrics than on EED metrics. Eighty-eight percent of EBD and 50% of EED hospitals surveyed reported that their facility collects data related to EBD on issues such as patient satisfaction or medical errors. On the other hand, only 63% of EED and 12% EBD of administrators reported that their facilities track EED data such as energy or water consumption. See Figure 1.

Figure 1. Rates of EBD and EED Data Collection



Of the facilities surveyed, most – 69% -- only collect one type (EBD or EED); facilities that collect one don't necessarily collect the other. A quarter of the facilities collect data on both topics, and 19% don't collect data related to either topic. Of the facilities that collect EBD data, 17% also collect EED data. (See Figure 2.) This is somewhat lower than the total percentage of facilities – 37% – that collect EED data. Of the facilities that collect EED data, half also collect EBD data. This is somewhat lower than the total percentage of facilities – 68% - that collect EBD data.

Figure 2. Prevalence of Data Collection of EBD and/or EED Data by Subject Facilities



For those facilities gathering data, the administrators were asked to provide examples of the data being collected. Of the EBD data types identified, the highest number of administrators (five) listed patient satisfaction. Two administrators listed staff satisfaction. Of the other EBD metrics identified, each was listed only once. Overall, patient-related metrics represent most of the EBD issues identified in the survey. Most EED data are related to energy consumption. Sixty percent

of the metrics identified relate to energy, however different facilities appear to be measuring it in slightly different ways. Two administrators identified total energy consumption and recycling as metrics for which their facilities collect data; the other metrics were only listed by one administrator each. See Figure 2.

Figure 2. Types of data being collected at EBD and EED best practice facilities.

Types of EBD Data Collected	Types of EED Data Collected
Patient health, safety and wellbeing	Energy
Patient satisfaction	Total energy consumption over time
Patient safety	Electricity
Clinical outcomes	Natural gas
Falls	Chilled water
Infection rates	Steam
Medical errors	Individual building energy use [for buildings on a campus]
Centralized vs. decentralized nurse stations	Central plant energy use [for an entire campus]
Perception of control	Energy use per square foot
Staff health, safety and wellbeing	Water
Impacts on staff[1]	Total water consumption over time
Staff satisfaction	Cooling tower make-up water
Fiscal health	Water use per square foot
Staff retention	Waste
Nurse time in patient rooms	Recycling
Aggregate metrics	Solid waste
Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) scores	
Centers for Medicare & Medicaid Services (CMS) process indicators	

[1] The language of the metrics in this list is taken directly from the surveys with minimal interpretation. "Impacts on staff" is a vague metric and can include several things, including staff satisfaction, efficiency, walking distances, or attrition.

Survey Lessons Learned

The hospital administrators were asked two final narrative response questions, both relating to lessons learned from their facilities. The first of the two questions was, "If you were to rebuild your facility, what changes would you make regarding EBD/EED goals?" Four EBD and five EED administrators responded to this question; most listed several proposed changes. The EBD administrators primarily suggested changes specific to building features, such as flooring type or waiting room design. For EED projects, on the other hand, only one administrator listed proposed changes to specific building elements; most of the comments focused on design process changes. Figure 3 presents the proposed building design changes and the proposed design process changes identified in the survey.

Figure 3. Proposed Building Design and Design Process Changes

EBD Building Design Changes	EED Building Design Changes
Rubber floors	Linoleum flooring
Increase work space for nursing staff closer to patient's room	Improve daylight harvesting
Private waiting areas for families instead of large waiting rooms for multiple units	Consider ground source heat pumps
Provide patient choices in waiting room seating	
Access to nature	
Art	
Improve wayfinding systems	
Improve lamp color	

EED Design Process Changes
Incorporate LEED® early in the design process.
Improve the disconnect between the building design. and ultimate use for a healthcare and research building.
Consider tenant-specific equipment during design
Increase the involvement of all levels of staff on EED

The final narrative response question was open ended in order to give the administrators the opportunity to provide additional comments on the larger topics of EBD and EED. Five administrators from each of the EBD and EED facilities responded to this question. In the case of one EED respondent and two EBD respondents, the comments were intended to clarify previous answers and did not provide additional relevant information. The other respondents, however, provided high level discussion on their implementation of and/or the relationship of EBD and EED; these responses are presented in Figure 4.

Figure 4. Selected Responses to Open-Ended Request for Comments

Comments from EBD Administrators 1. There is no relationship between Evidence and Eco based design and they should not be "piggybacked" 2. There is no question that Evidence Based Design is instrumental in both the patient and staff satisfaction at our facility. 3. Assuming that an owner is committed to both, one need not be sacrificed for the other. However, accomplishing both is often a challenge.
Comments from EED Administrators 1. Determine your sustainability goals early in the project, and employ an integrated design team. By keeping sustainability in the front of the designers, the successes are much bigger and easier. 2. We have found that some "typical" sustainable design ideas run contrary with Hospital licensure or building codes. Our project was started before the Green Guide for Healthcare, and we were continually being measured against a generic building type. 3. After completing the survey one theme that seemed implicit in the questioning of this survey was this idea that eco-effective design and evidence based design were separate design strategies and we had to choose one over the other. This certainly may apply to small design features [this healthcare organization] incorporated in its hospital, however, we tried to design and select features from both design fields. One thing we took away from our project is you have to look at the muliple impacts that the design will have on patients, employees and the community and factor how evidence based design and eco-effective design can enhance the overall look, feel and function of a hospital. 4. Focusing on operations is also a key to a successful program.

Literature Review

Direct relationships between EBD and EED were rarely discussed in the literature reviewed; few sources specifically targeted both topics in the same article. Some sources about a subject hospital barely mentioned even one of the EBD or EED concepts as a driving design strategy,

innovation or goal. Overall, most discussion of EED facilities focused on how the building itself was designed to reduce harm to the natural environment, not to create a "healing environment." This concept, on the other hand, was repeated regularly throughout the literature related to EBD.

Both authors' text and quotes from hospital or design team members portray a wide range of often incongruous opinions and perceptions. Ideas expressed in one article might contradict those expressed in a different article about the same facility, especially when discussing the value of an innovation, or the degree to which EBD or EED informed any design decision or innovation. The perceptions on the value of EBD or EED ran a broad spectrum from positive, beneficial and synergistic (e.g. press releases, trade publications and marketing materials) to highly scrutinized (e.g. some popular magazines, newspaper articles, peer reviewed publications, and case studies).

Most of the reviewed literature either implied or formally stated that, philosophically, healthcare/EBD are generally compatible with and/or supportive of EED/sustainability, especially with regard to heath IEQ related issues. The literature included many examples of EED strategies that were in direct synergy with EBD strategies. For example, one project included a green roof over their loading dock in order to provide a pleasing view to patients -- an EBD goal. The roof also fulfills EED goals of managing stormwater and reducing the project's heat island effect (Eagle, 2007). A second project noticed an added benefit to their EED daylighting design strategies of lowered absenteeism and turnover in staff and higher patient satisfaction scores (Van Cleave & Rehnberg, 2004).

There were only a few examples of projects that incorporated both EBD and EED strategies as part of their design. One subject hospital that was steeped in evidence-based design strategies also adhered to incorporating a variety of EED strategies as part of their mission to help produce better healthcare outcomes for both patients and staff. Likewise, designers of an EED project defined early on in the design process that "Green building is not only about increasing efficiency and saving money, but reducing negative impact on building occupants. That includes natural exterior lighting, which some studies show improves patient morale and decreases use of analgesics." (Weisel, 2008).

In practice, however, some of the common green building concepts are more difficult or impossible in the healthcare environment, especially where codes require resource-intensive systems. For example, the EED goal of achieving a smaller building footprint is in direct conflict with the EBD strategy of single patient rooms. Several sources also cited water reduction and graywater use to be a challenge in healthcare due to infection control issues and code conflicts.

Strategy Matrix

The strategy matrix identifies several hundred meaningful intersections between one EBD strategy and one EED strategy. (See Figure 5.) Despite this large number, however, a majority of the strategy combinations don't have a real relationship. For example, EED strategies like natural stormwater management or cool roofs simply don't impact EBD strategies like HEPA filtration or focused task lighting. However, each of those strategies do have a relevant

Figure 5. Strategy Matrix

Key
- ● = Clear synergy between strategies
- ○ = Possible synergy between strategies
- ● = Clear conflict between strategies
- ○ = Possible conflict between strategies
- ○ = Strategies are related

		Healthy Experience														Safety														Operational Efficiency						Technology					Life Cycle Flexibility									
		Clear Wayfinding & Access	Short Travel Distances	Clear separation of staff activity from client/patient activity	Daylight at Interior	Access to Nature	Patient Privacy	Positive Distraction (art, music, entmt., interaction)	Views to the exterior	Operable Windows	Noise Reduction, Audible Privacy	Patient Choices	Control of Environment	Adequate & Convenient Parking by Occupant/Use	Respite Opportunities (indoors & outdoors)	Pharmaceutical Safety (Low Distraction, Closed Loop)	Critical View Lines (surgery, imaging, etc.)	Focused Task Lighting	Convenient Consult Spaces	Lighting design to reduce medical dispensation and surgical errors	Patient separation (private rooms, holding, recovery, etc.)	Handwash Safety (Sinks & Gel)	Robust Air and Ventilation	Pressurizations & HEPA Filtration	Nontoxic Materials	Appropriate Materials (Durability, Cleanability, Microbial Issues, etc.)	Assistive movement (lifts, grab bars, double doors)	Handed Rooms	Acuity Adaptable	Adequate Waiting/Sleep Space	Alignment with Infection Control/Safety/MRI Policies	Separate Flow (patient types, staff, materials)	Supply Inventory	Program & Circulation Efficiency	Best Practice Floor to Floor Heights	First Cost/Lifecycle Cost Strategy	Philanthropy	Advanced Communication Systems, Healthcare IT, Electronic Records	Remote Support	Patient Monitoring	Integrated Interventional Platform	e ICU	External Expansion Options	Internal Conversion Options	Excess Capacity of Bldg. Systems	Non-limiting Column Bay Spacing	Modular Planning Concept	Building Systems Zoned Horizontally	Building Systems Zoned Vertically	Acuity Convertible Rooms
	Integrated Design Process												○							○					●									●														
	Health & Environmental Mission Statement				○																				●																								
Sustainable Sites	Avoid Undeveloped & Prime Agricultural Sites					○ ●								○ ●	●																																		
	Avoid Ecologically & Culturally Sensitive Sites					○ ●								●	●																																		
	Dense, Walkable Community					●					●			●	●																																		
	Provide Alternatives to Car Use/Parking		○			○								●																																		
	Prevent Erosion & Sedimentation																																															
	Natural Stormwater Management																														●																	
	Open Space, Green Roofs & Restore Habitat					●			○			○			●																																		
	Provide Shade &/or Light Colored Paving														○																																		
	Reduce/Eliminate Light Pollution								●				○					○		●																												
Water Efficiency	Efficient Plumbing Fixtures																					●								○ ●																	
	Treat Wastewater on Site																													●																	
	Use Gray or Rainwater for Irrigation/Equipment					○																								●																	
	Water-Efficient Medical Equipment & Processes			○																																											
	Water-Efficient Commercial Kitchen																																														
	Low-Water Cooling Towers																																														
Energy & Atmosphere	Appropriate Orientation for Energy Efficiency				●				○	○																																					
	Thin Floor Plate	○			●				●	●							○			○	●											○		○ ●		○ ●												
	High Perform. Façade & Right-Sized Glazing				●	○			○	○	●		○							○															○	●												
	Right-Sized Air Change Requirements									○ ●	○												●	○							●																
	Energy-Efficient Equipment/Appliances																						●	●							●						○	○	○		○							
	Energy-Efficient Lighting/Controls	○			○			○					●					●		○ ●											●																	
	VAV, Heat Exchange & Radiant Systems									○			○										○	○ ●							○ ●																	
	Cool Roof								●																																							
	Measurement & Verification																						○								●																	
	Commissioning																						○								●																	
	Low-Impact Refrigerants																						○	○	○																							
	On-Site Renewables & Green Power																								○						● ○		○															
	Cogeneration, Thermal Energy Storage																														● ○																	
	Overall Building Energy Efficiency & Total En. Use			○	●				○	○ ○			○ ○					○		○	●		●	●							● ○	○																
Materials & Resources	Renovate an Existing Building																								○									○														
	Reuse Materials & Furnishings																								○	○ ○					●																
	Sustainably Sourced Materials																								○																						
	Reuse or Recycle Construction/Demolition Waste																														●																
	Building Recycling/Composting Plan																														●																
	Material Life Cycle Analysis (LCA)																								●						○																
	Design for Flexibility																○	○ ○							○				●					○			●					● ●	● ●	● ●	● ●	● ●	● ●	● ●	●
	Design for Durability																								●						● ○																
	Reduce Quantity of Materials/Resources Used			○																		●			●	○	○				○		○		●												
Indoor Environmental Quality	Nontoxic, PBT-Free Materials																								●	○ ○					○ ○																
	Select Materials for Green Cleaning																								○	○					○ ○																
	Effective Air Circulation Strategy									● ○	○		● ○										● ○	○												○								○				
	Monitor CO2 & Fresh Air Delivery									○													●	○							● ○																
	Construction IAQ/Emissions Control																							○	●																						
	Pollutant Source Control Strategy					○				○													○	●	○						● ○																
	Wind tunnel Testing, Air Intake & Pedestrian Comfort					○																	●	○							● ○													○				
	Thermal Controllability (All User Groups)									●		●	●								○		○																								
	Lighting Controllability (All User Groups)				○ ○							●	●				○	○		● ●	○																										
	Visual Comfort Analysis				○	○			○	○			○								○	○																								
	Thermal Comfort Analysis									○			○		○									○																								
	Operable Windows					○			○	●	●	●	●											○	●						○ ○																○
	POE	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○					○	○	○			○														
	Daylight & Views	○		○	●	○	○	●	●	○			○ ○								○															○				○	○	○	○	○				
	Acoustic Control & Mitigation			○		○	●			○	●	○	●		○								●	○																				○				
	Relaxing Nature Images (2-D)	○				●		●							○																																
	Access to Terraces/Courtyards/Gardens	○			○	●		○	○			○			●		○														○						○										
	Staff-Only Outdoor Spaces			●	○	●									●																○						○									
	Design to Support Circadian Rhythm (patients/staff)				●	○	○		●	○	○		○		○			○		○ ○	○																										
	Views or Access to Water	○				●	○	●	○		○				○																○						○	○									
Operations	Staff, Patient & Visitor Sustainability Education	○			○	○		○	○	○		○	○		○																						○	○									
	Low Impact Bldg. Exterior & Hardscape Mgmt.																								○						● ○																
	Integrated Pest Management (intr & extr)																								○						● ○																
	Erosion Control & Landscape Mgmt. Plan					○			○																○						● ○																
	Serve Sustainable Food											○																			○																
	Reusable Food Service Ware																								○						○																
	Reduce Disposable Products																					○ ○				○ ○					○																
	Solid Waste Reduction in Purchasing																					○									○																
	Recycled Content & Chlorine Free Office Products																					○			●	○					○																
	Toxicity Prevention in Purchasing																								●	○					○ ○																

relationship with at least one other strategy from the opposing category. Of the EED categories, IEQ strategies had the strongest correlation with EBD strategies overall, and especially with those in the Healthy Experience (HE) category. Likewise, among EBD categories, the HE strategies had the strongest correlation with EED, and especially with IEQ strategies. In addition, some EBD and EED strategies are the same or nearly the same, and are listed under both topics. These overlapping strategies are related to daylight, views, access to nature, acoustics, operable windows, controllability, and nontoxic materials.

In addition to the overlapping strategies listed above, EBD strategies with many synergistic relationships with EED strategies include Patient Privacy; Positive Distraction; Patient Choices; Respite Opportunities; and Lighting Design to Reduce Medical Dispensation and Surgical Errors. Likewise, the following EED strategies have several synergies with EBD strategies: Open Space, Green Roofs & Restore Habitat; High Performance Facade & Right-Sized Glazing; Energy Efficient Lighting and Controls; Visual Comfort Analysis; Thermal Comfort Analysis; Wind Tunnel Testing for Air Intake Quality and Pedestrian Comfort; Design to Support Circadian Rhythm; Access to Water; and Staff, Patient & Visitor Sustainability Education. Although these strategies are all primarily in synergy with the strategies in the opposing category, some also may have conflicts.

On the other hand, a few strategies in each category are primarily in conflict with strategies in the opposing category. Within EBD, strategies that typically lead to a larger floor plate -- e.g. Separate Flow for Patients, Staff, Materials -- are in conflict with the EED goals of reducing energy and material use. Given this, it is no surprise that within EED, Overall Building Energy

Efficiency and Total Energy Use conflicts with several EBD strategies, though it is also in potential synergy with some. The EED strategy of Right-Sized Air Change Requirements is also broadly in conflict with EBD's Life Cycle Flexibility strategies. To right-size air change requirements typically involves setting ventilation rates for a specific use or code requirement, which may prevent future changes to space types that require higher air change rates than the original functions did. Most strategies that conflict with several opposing strategies, however, also synergize with several other strategies. Right-Sizing Air Change Rates synergizes with the EBD strategy of Noise Reduction; unusually high ventilation rates can lead to unpleasantly loud mechanical systems. The EBD strategy Alignment with Infection Control/Safety Policies is another good example -- it has at least 10 conflicts and 10 synergies with EED strategies. In some cases, the relationship between two strategies might simultaneously result in a conflict and/or a synergy. For example, in some conditions operable windows might be in conflict with infection control and safety issues -- bacteria from exiting one window might enter the next -- but in other conditions -- a natural disaster, for example -- operable windows might improve infection control and safety if a facility attempts to operate on limited power for an extended period of time.

DISCUSSION

Facility Data Collection

Overall, more facilities are collecting data on EBD issues than on EED issues. There are likely several reasons for this. First, the administrators typically considered EBD to have played a

more significant role in the design process and in clinical and administrative decisions than did EED (Shepley et al, 2009). With more emphasis on EBD issues than EED issues, it is not surprising that more facilities are collecting data on EBD. Furthermore, the administrators indicated that EED played a more significant role in the design process than in clinical or administrative decision making (Shepley et al, 2009). With EED less of a focus during building operation, facilities are not likely to track the performance or success of EED issues.

In addition, professional and academic communities have fostered a culture of EBD research and research dissemination since the 1980s, while sustainability advocates are only beginning to show interest in this area. For example, the Center for Health Design's Pebble Project program has set up a formal structure through which healthcare organizations can become "Pebble Project Partners." The intent is for Pebble Projects to form hypotheses during the design phase, execute them in the design, and then study their effectiveness once the building is in operation. The Center for Health Design (CHD) provides a format for these steps, and for disseminating the results of the research (Pebble Guidebook, 2008)[2], including a matrix that helps to identify and track research outcomes with respect to the groups of occupants being studied. This matrix includes topics related to those identified in the EBD list of Figure 2, as well as a category for "environmental/sustainability" (Pebble Matrix, 2004). However, the newly released Pebble Guidebook is largely replacing this tool. Environmental sustainability research outcomes are not directly addressed in this document (A. Joseph, private communication, 2008). Six of the eight EBD facilities surveyed are Pebble Projects or Pebble Project Alumni; the remaining two EBD facilities are Planetree Hospitals. Planetree is a model for providing patient-centered care; many

[2] See http://www.healthdesign.org/research/pebble/ for more information on The Pebble Project program.

Planetree and Pebble Project goals and strategies are closely aligned, although the Planetree organization does not provide a structure for research and dissemination.[3] No EED facilities surveyed are either Planetree Hospitals or Pebble Projects.

No equivalent organization exists to guide facility owners and design teams of green buildings in the research and dissemination process.[4] Although the Green Guide to Healthcare (GGHC™) suggests the relevance of project-based research, there is little organizational infrastructure to support this, and GGHC™ is still relatively young.[5] Seventy-five percent of the EED facilities are LEED® for New Construction (LEED® NC) Certified, but the LEED® NC system does not require any kind of monitoring or data collection. Within LEED® NC, one point is available for installing equipment that will later allow building owners to track energy and water use, however, only equipment installation is required -- a facility does not actually have to track data to achieve the point. LEED® for Existing Buildings Operations and Maintenance (LEED® EBOM) addresses and rewards this activity, however LEED® EBOM is not yet as widely used as LEED® NC, and is extremely rare in healthcare; no hospital projects had been certified under LEED® EBOM as of April 2009 (US Green Building Council, 2009).

[3] See http://www.planetree.org/ for more information about Planetree hospitals

[4] On the other hand, professionals interested in sustainability have had the opportunity to become LEED Accredited Professionals since 2001, whereas the parallel Evidence-Based Design Accreditation and Certification (EDAC) is only now becoming available. The EDAC accreditation directly addresses the research process, whereas LEED accreditation does not.

[5] The Green Guide to Healthcare was piloted in December 2003 and released in September 2005.

Although dozens of research institutions exist to study dozens of topics related to green building (Baum, 2007), very little research is focused on assessing the success of specific strategies within a built facility. The US Green Building Council has identified this as a major gap in the existing body of green building research; its *National Green Building Research Agenda* includes "performance metrics and evaluation" as one of 12 priority topics for further study (Bohm, Ed., 2008), and a second USGBC-sponsored study concludes that we need significantly more data on actual building energy performance (Turner & Frankel, 2008). According to the research agenda document, relevant metrics and evaluation procedures have not been fully developed for many relevant topics and issues (Bohm, Ed., 2008). All of the types of EED data being collected are identified in the USGBC's research agenda as highly relevant and necessary.

Not only are fewer facilities collecting data on EED metrics once a facility is built, but facilities are also collecting data on a relatively narrow range of topics. The EED metrics identified all focus on resource efficiency: energy use, water use, and waste disposal. Of these, most are various energy-related metrics. The EBD metrics identified, on the other hand, address a broad range of topics, although the majority of them focus on patient and clinical issues. All of the topics identified by the administrators surveyed are issues that the Center for Health Design promotes.

Survey Lessons Learned

First, it is noteworthy that the EBD administrators all focused their "lessons learned" comments on specific building features. Current models for EBD research and literature often place an

emphasis on discreet changes or alterations that facilities can make to achieve a specific end, such as the installation of patient lifts in order to reduce patient and staff injuries from lifting patients manually (Joseph & Fritz, 2006). Although at least one facility is undertaking research that addresses big-picture, holistic issues,[6] this is frequently not the case.

Of the lessons learned specific to building design, most of the EBD and all of the EED strategies proposed are relatively well accepted and acknowledged strategies within their respective category. Of the eight EBD building design changes proposed, only one – access to nature – overlaps with EED goals. Two of the three EED strategies, however, overlap with EBD goals: linoleum flooring and daylight harvesting. Linoleum is a healthier alternative to vinyl, and daylight "harvesting" refers to the desire to intentionally and actively bring daylight into a deep plate, often through daylighting fixtures, courtyards, atria or skylights. This is an important challenge for hospitals, which tend to use deeper floor plates than other building types.[7] The third proposed EED design change, ground source heat pumps, is a strategy to use the thermal stability of the earth adjacent to a building to improve energy efficiency.

In contrast to EBD administrators, EED administrators mostly addressed design process issues. Only one respondent suggested that the facility would change specific building features without also addressing the design process. In one survey, specific building features identified by the

[6] Laguna Honda Replacement Hospital in San Francisco, CA is undertaking EBD research through the Center for Health Design on improved quality-of-life and several other topics. The research is scheduled to take place in 2009 and 2010 (Cohen and Cohen, 2008).

[7] This study limited the subject hospitals to facilities in North America. Daylighting and daylight harvesting is comparatively more prevalent in Europe.

administrator were couched as examples of problems caused by a faulty design process. For example, the administrator said that the facility was having a difficult time providing adequate water to sterilizers and adequate cooling to freezers. These problems were caused by a disconnect between the design process and the tenant end users; the heavy equipment was not accounted for when the building systems were sized. This is not necessarily a problem specific to sustainability -- if a building is designed for one use but a different tenant or use ultimately occupies the space, then challenges or conflicts are likely to arise. However, these conflicts may be more pronounced in projects that are driven by sustainability, because right-sizing of building systems and equipment is often a design goal; running mechanical and other systems at a reduced capacity is typically significantly less energy efficient than running the same systems at or near capacity. If a facility's systems are right-sized for the immediate demand, there may not be much additional capacity for unexpected uses at the initial occupancy or in the future. While this may be a problem for any building type, it is a potentially larger one for healthcare because the utility requirements for equipment can be significantly higher than in conventional facilities.

Several similar themes emerged from the EED administrators. One theme is that the successful execution of sustainable designs is partially dependent on the ability to address and incorporate sustainability early, often, and with as many relevant stakeholders as possible. Two respondents emphasized the importance of the role of end users or tenants in the design process. Two others suggested that sustainability should be integrated early in the design process, and one addressed the need to continuously keep sustainability on the table. These comments reinforce prevalent concepts that are frequently cited as critical elements of the green building process (e.g. Syphers, Baum, Bouton & Sullens, 2003; Mendler, Odell & Lazarus, 2005).

Several administrators from both EBD and EED facilities directly addressed the relationship between the two design practices. One EBD administrator took clear stand with the comment, "There is no relationship between Evidence and Eco based design and they should not be 'piggybacked'." Two other administrators, however, challenged the notion that EBD and EED are or should be addressed and discussed separately. According to one respondent, the survey's premise suggested that EBD and EED are separate and that facilities must "chose one over the other" is faulty; this administrator stressed the importance of finding synergies between strategies that support both goals. Similarly, a second respondent said, "Assuming that an owner is committed to both, one need not be sacrificed for the other."

This administrator conceded, however, that "accomplishing both is often a challenge." A second facility also found that some standard green building practices conflict with hospital licensure or building code requirements. Before publications like GGHC™ were developed, hospitals that wanted to go green had few resources beyond those developed for generic building types. These conflicts and challenges raise the issue that it is critical for design teams to understand healthcare-specific building requirements and integrate these with sustainability practices.

Literature Review

Perceptions vary widely, but many are optimistic about integrating EBD and EED. Both EBD and EED are still in their infancy in healthcare architecture. Many of the sources treated the two concepts, but especially EED, as novel. This is likely to change as sustainability becomes

increasingly commonplace within both healthcare and the larger national discourse currently underway. The perceptions of the relationship between EBD and EED from the literature review are directly parallel to the perceptions of the subject hospital administrators, indicating a general alignment between their private survey responses and the information being published publicly. Overall, the attitude of some of the literature is more positive than the attitudes expressed in the surveys, but this is not surprising given the often propagandistic nature of these publications. In some cases, the authors and contributors to the articles may have been trying to proselytize EBD or EED, and may have been less likely to discuss their problems. Many sources, however, were candid about challenges and failures.

Strategy Matrix

The strategy matrix is a simplification of a large, complicated set of challenges: how do we integrate as many EBD and EED strategies as possible to build better healthcare buildings? To achieve this goal, each set of relationships must be carefully examined -- the devil is in the details. Different individuals on a project team and different project teams will likely interpret these details somewhat differently. Within the four sets of people independently filling out this matrix, over half of the relationships were only identified by one or two groups. While this is in part due to differences in specialized knowledge, it also underlines the notion that these concepts are neither widely nor uniformly understood. All of the individuals who participated in this phase of the research said that they benefited significantly from going through the thought process of identifying specific conflicts and synergies, and will be able to translate that thinking to future projects.

Results from the strategy matrix are an amalgamation of the outcomes of other phases of the research, with an additional round of analytical thought at a more detailed level. Given this, the matrix findings generally reinforce the findings from other phases of the project. The graphic format makes the information more visually understandable while at the same time allows for a higher level of specificity with EED and EBD strategies.

The matrix does have a few limitations, however. Within both EBD and EED, some strategies conflict with other strategies within their same category, but this matrix doesn't address conflicts and synergies within a category -- only relationships between categories. For example, the EBD goals of Operable Windows and Pressurizations can conflict with each other, as can the EED goals of Access to Gardens and a Dense Walkable Community. Also, despite the goal of being thorough, some strategies may be oversimplified, and others may be missing altogether. The matrix includes a broad range of most of today's most common EBD and EED concepts, but doesn't represent a one hundred percent exhaustive list, nor does it account for lesser known strategies that may become more prominent in the future. The matrix format can easily be adapted over time, however, to address shifts in the profession or project-specific demands.

CONCLUSIONS

EED projects have a lot to gain from the EBD culture of research and dissemination, whether or not the topics of data collection include more conventional (non-ecological sustainability) issues. EED is comparatively newer to healthcare architecture than is EBD; significant research efforts

on sustainability issues are clearly necessary. Projects that are considering collecting data on EED issues can look for input to one of the many organizations focused on this topic (e.g. the Environmental Design Research Association and the Center for Health Design), or one of several universities specializing in health design research (e.g., Clemson University, Georgia Tech, University of Wisconsin, University of Detroit, Mercy, University of Illinois, University of Southern California, and University of Arizona). They should also consider the USGBC's *National Green Building Research Agenda* for a discussion of critically relevant topics.[8] Although EBD has a more refined and structured research and dissemination process than EED does, it is not yet mainstream either. Further growth and development of both is needed.

The lessons learned provided by the nine facilities that provided narrative responses generally confirmed what others are saying: sustainability needs to be incorporated into projects sooner, more frequently in the design process, and with more stakeholder participation. The fact that EED respondents focused on process related issues, whereas EBD respondents did not, emphasizes the importance of the design process in implementing EED practices. The final question of the survey was open-ended, asking administrators to provide final comments. It is striking that without any prompting or direction on this topic, several respondents to this question addressed the design process and, more specifically, that EED and EBD do not necessarily need to be considered as either/or options -- they can both be included simultaneously on a project. Although there were mixed opinions about the relationship of EBD and EED – including whether or not they even have a relationship – more respondents supported

[8] The National Green Building Research Agenda is available for download from the USGBC at http://www.usgbc.org/ShowFile.aspx?DocumentID=3402. Additional USGBC research publications are available at http://www.usgbc.org/DisplayPage.aspx?CMSPageID=77.

integration than separation. This is consistent with other findings from the same survey which indicate that, although a few specific EBD and EED design strategies are in conflict, most are either in synergy or have no direct relationship (Shepley et al, 2009).

The strategy matrix is an additional tool in trying to understand clear and potential conflicts and synergies. The clear synergies are win-win relationships that can hopefully be integrated into every project, whereas the clear conflicts are challenges that may need to be either avoided or overcome through other measures. Teams should look most critically at the potential conflict or synergy relationships, with the goal of achieving the potential synergies and avoiding the potential conflicts. Because the details of implementation are often critical to success, however, design teams shouldn't take all of the generalized conflicts and synergies at face value without further project-specific consideration. Finally, each of the points of intersection on the matrix could easily be expanded into full-blown topics for future research.

Overall the separate phases of research reinforced the same conclusions: although evidence-based design and eco-effective design are clearly compatible, thoroughly integrating them is not always clear cut. Strategies perceived as conflicts by some people may actually become synergies (Shepley et al), and synergistic relationships could become conflicting if not well executed. EBD and EED are both relatively new within healthcare architecture and both continue to grow in popularity; more integrated solutions are likely to arise.

As global environmental conditions continue to decline, the healthcare industry will need to reexamine the immense resource requirements of hospital buildings. With the cost of healthcare

skyrocketing and the US population aging, innovations are more necessary than ever. Both the quality of healthcare and of the natural environment have the capacity to improve through simultaneous integration of EBD and EED.

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DISSEMINATION

The research prompted the writing of a draft publication that has been submitted to a peer-reviewed journal for publication in Spring 2009. One of the principal investigators discussed the project at Healthcare Design 08, the annual Center for Health Design conference, on November 10, 2008 in Washington D.C., and a second principal investigator discussed it at Greenbuild, the annual US Green Building Council conference, on November 21, 2008 in Boston. A paper on the research process was presented at the Architectural Research Centers Consortium (ARCC) Conference in San Antonio April 19, 2009, and was accepted to the conference proceedings. Two principal investigators will present results at CleanMed in Chicago May 19, 2009, and will present additional findings at Healthcare Design 09 in November 2009. The Boston Society of Architects, a second funding agency, will also be publishing results. Additional publications and presentations are expected to follow.

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